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STUDY OF SOUNDPROOFING PUBLIC BUILDINGS NEAR AIRPORTS.(U)

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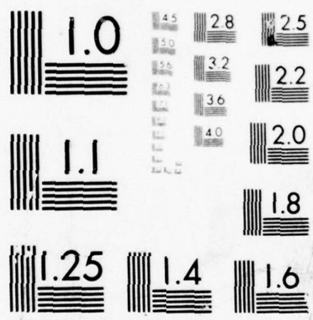
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REPORT NO. DOT-FAA-AEQ-77-9

LEVEL II

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STUDY OF SOUNDPROOFING PUBLIC BUILDINGS NEAR AIRPORTS

Trans Systems Corporation, Vienna, Virginia
in Association with Wyle Laboratories

April 1977

FINAL REPORT

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Office of Environmental Quality

Washington, D.C. 20591

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Technical Report Documentation Page

1. Report No. DOT-FAA-AEQ-77-9	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle STUDY OF SOUNDPROOFING PUBLIC BUILDINGS NEAR AIRPORTS		5. Report Date April 1977
		6. Performing Organization Code SB 3-4-4-8(a) 77C-372
7. Author(s) Trans Systems Corporation; Wyle Laboratories		8. Performing Organization Report No. TS-101
9. Performing Organization Name and Address Trans Systems Corporation, 118 Park Street, S.E., Vienna, VA 22180; Wyle Laboratories, 2361 Jefferson Davis Hwy., Arlington, VA 22202		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FA77WAI-706
12. Sponsoring Agency Name and Address Federal Aviation Administration, Office of Environmental Quality, Washington, D.C. 20591	Final rpt.	13. Type of Report and Period Covered October 1976-April 1977
		14. Sponsoring Agency Code
15. Supplementary Notes		275 p.

16. Abstract

Pursuant to Special Studies, Section 26(3) under Appendix B, of Airport and Airway Development Act Amendments of 1976, Public Law 94-353, this study was undertaken to develop the data and procedures which can be used to determine the feasibility, practicability and costs of soundproofing public buildings near airports. Costing of soundproofing public buildings includes: schools, hospitals, and public health facilities near airports.

17. Key Words Aircraft Noise Impact; Aircraft Noise Measurement; Airport Land Use; Building Noise Attenuation; Public Buildings, Schools, Hospitals, Health Facilities; Soundproofing.	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

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PREFACE

This study was performed under Section 26(3) of the Airport and Airway Development Act Amendments of 1976 (Public Law 94-353, July 12, 1976) which states in part:

> "Special Studies
> Section 26. The Secretary of Transportation shall conduct studies with respect to - (3) the feasibility, practicability, and cost of soundproofing of schools, hospitals, and public health facilities located near airports."

This study was undertaken by the Trans Systems Corporation, Vienna, Virginia, in association with Wyle Laboratories, under the direction of the Office of Environmental Quality, Federal Aviation Administration.

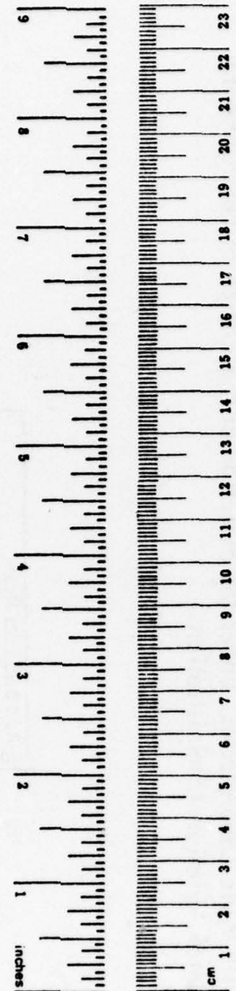
The opinions, statements, and findings contained within this report are those of the contractors, and not necessarily those of the Federal Aviation Administration.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

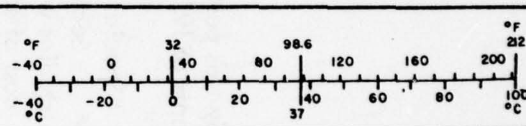
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

This report is in response to the requirement of the Special Studies, Section 26(3) of the Airport and Airway Development Act Amendments of 1976 (Public Law 94-353). The report sets forth our findings with respect to:

- The feasibility and practicability of soundproofing of public buildings near airports;
- The extent of funding and the priority of such programs;
- The manner in which soundproofing can be carried out; and
- The views expressed by planning agencies, airport sponsors, and other concerned persons or groups.

This study is largely based on existing and on-going research into threshold levels of noise disruption, methods of noise measurement and prediction, and architectural and engineering building noise attenuation. The results include conclusions and supporting data relative to the state, regional, and national impact of aircraft noise; the costs and costing methodology; the benefits of soundproofing; and the views and opinions of state, city, school, and airport officials.

Specific Results

A careful and comprehensive search of the literature provided specific interior threshold levels of noise impact. These threshold levels are levels of noise above which noise interference can occur. The major problem in schools is the disruption of classroom communications. Depending on the actual level of noise intrusion, teachers must shout to be heard; or in many cases, teachers must stop teaching for the duration of the flyover. Often students miss information and assignments. Both teachers and students have reported noise impacted classrooms as uncomfortable, distracting, and not conducive to learning. Reference research indicated that the threshold of disruption in classrooms is approximately 45 dB.

Reference research led to the findings that the major noise intrusion problem in hospitals and public health facilities is the disturbance of sleep. Although the research and medical evidence is not completely clear, sleep is recognized as an integral part of the healing process, and the continual disturbance of sleep can have a negative impact on healing. It was determined that the threshold for the disturbance of sleep was approximately 40 dB. Aircraft noise intrusion at a level above this begins to have a direct effect on sleep.

Soundproofing of schools minimizes and considerably reduces the disruptive effects of aircraft noise on the communication and learning process within classrooms. The soundproofing of hospitals minimizes or reduces the disruption of sleep, thereby improving the recuperative and healing process.

Measurements of exterior and interior noise levels of approximately 10 buildings at each of three airports were undertaken. These included Los Angeles International, Stapleton (Denver), and Logan International (Boston). These measurements were made to support a noise prediction methodology based on the exterior noise level and the basic construction of the building. It was found that the interior noise level, within a classroom or hospital room, could be determined from a knowledge of the exterior noise level and the building construction.

In order to develop a complete representative data bank of hospital and school construction, not only buildings around Los Angeles International, Stapleton, and Logan International were surveyed, but also on-site architectural surveys of impacted buildings around Miami International, Sky Harbor (Phoenix), and William B. Hartsfield (Atlanta), were conducted. Each city was chosen as a representative of a region of differing construction practice. Thus, the 60 buildings surveyed were representative of each of six regions of different construction practice and, in total, representative of all impacted schools and hospitals nationwide.

The next task was to determine the architectural modifications that were feasible in the reduction of aircraft noise. The most common modifications involved windows, either double glazing or filling in. Other modifications that were possible involved wall, ceiling, and roof modifications. Some buildings required the baffling of vents, and the sealing of doors. These modifications were found to reduce the level of noise.

Modifications to the 60 buildings were then costed out to determine average building, room, and square foot costs within each of the six regions. These average figures provided the basis for projecting the national, regional, and state costs.

The magnitude of impact was determined by identifying all schools and hospitals located within the 30 NEF curve, plotted on U. S. Geographical Survey maps. Curves were plotted for all large and medium hub airports, and a sample of small airports. Using a set of single impact contour overlays provided the estimate of external noise. Thus, over 800 impacted buildings were identified and listed. A statistical projection was then applied in order to develop the nationwide population of impacted schools and hospitals. Compilation of these data by construction region as well as by state provided the regional and statewide impacts.

Compilations of these data were used to estimate the cost of modifying all buildings. Cost estimates were computed on the basis of cost per square foot per "delta" noise reduction (ΔNR) to be achieved. Thus, the cost of any building can be estimated by knowing only the approximate square footage and the NR desired. In addition, statistical projections were performed to estimate the costs to all buildings.

The nationwide costs to rehabilitate impacted buildings to feasible and practical limits were calculated to be $147,800,000 for schools, and $56,500,000 for hospitals and public health facilities, making a total rehabilitation cost for all buildings of $204,300,000. The number of schools is 1,057, and the number of students is 707,370. The number of hospital and public health facilities is 89, and number of patients is 30,806. The total number of impacted occupants is 738,176.

The expected benefits of soundproofing were calculated in a variety of ways. One monetary benefit to be achieved by soundproofing is the recovery of lost teaching time. This time has a value since teachers are paid for the time they must waste during the noise interruption. Benefits resulting from improved patient recovery time, and from energy were also calculated.

In the final chapter of this report, the views and opinions of concerned parties are presented, including state, local, and school officials. These opinions were not directly solicited, but rather were noted and documented whenever offered. Generally, soundproofing as a means of alleviating aircraft noise instrusion, is seen as a positive and desirable activity.

CHAPTER I

INTRODUCTION

This project was undertaken in response to the Special Studies requirements of Section 26(3) of the Airport and Airway Development Act Amendments of 1976.

A study was conducted to determine the impact and potential benefits of soundproofing schools, hospitals, and public health institutions located near airports as a means of alleviating the impact of aircraft noise.

Included within the scope of the study was the measurement of noise at three separate geographical locations, on-site architectural and engineering building investigations of noise impacted hospitals, schools, and public health facilities in six construction regions, and the statistical projection of data to determine the national impact. This effort was based on careful and detailed analyses of the available state-of-the-art and literature reviews in order to study the problems and procedures of soundproofing from all perspectives and in significant depth, providing the development of methodologies, procedures, and results.

The objectives of this study were to:

- Develop a set of data and procedures leading to the determination of the feasibility, practicability, and costs of soundproofing public buildings near airports as a means of alleviating the impact of aircraft noise.

- Determine the magnitude of the problem by quantifying the impact of aircraft noise on occupants in terms of numbers of people exposed to various levels of interior noise.

The study consisted of four basic tasks. The first task involved the application and documentation of current analytical procedures for predicting and assessing the interior noise levels produced in schools, hospitals, and public health facilities due to nearby aircraft operations. Included in this task was the identification of appropriate noise criteria and the verification of predicted interior noise levels by field measurement. Task two was to provide an estimate of the total number of public buildings and occupants exposed to aircraft noise within a specified area around airports. The third task was to develop estimates from a construction cost data base which relates the cost of building construction and rehabilitation to the sound attenuation achievable. The fourth task was to consult with organizations and authorities involved in the aircraft noise problem and establish the current level of understanding regarding the application of building soundproofing. Figure I-1 shows an overview of the study.

Chapter 2 covers the development and assignment of threshold levels of interior noise. The study required the determination of base levels of interior noise. These levels were not used, nor should they be viewed, as interior noise level standards but rather as a level above which aircraft noise could cause interference with communications in schools and

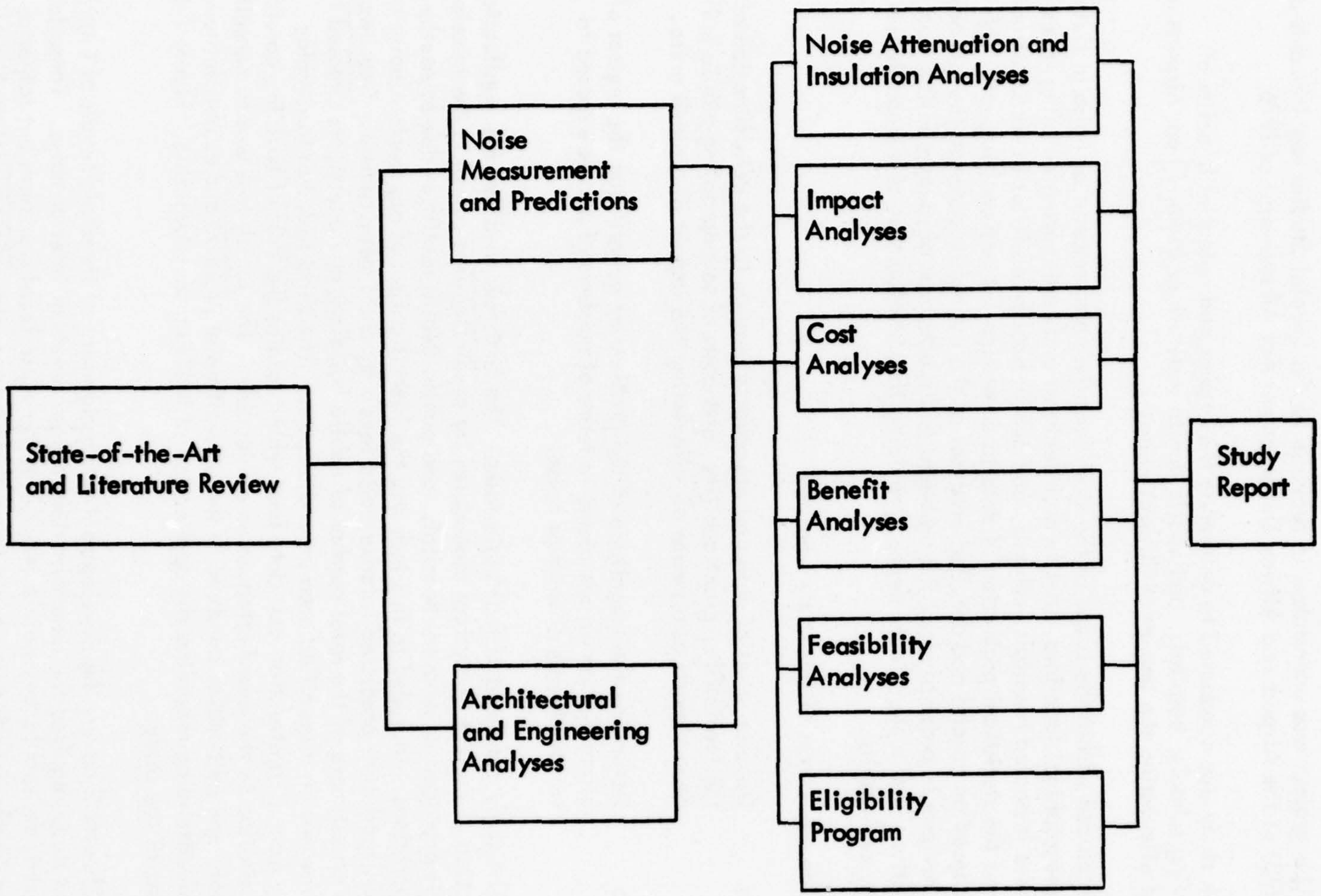

FIGURE I-1. OVERVIEW OF THE STUDY

sleep in hospitals and public health facilities. The determination of noise threshold levels was made after an extensive state-of-the-art analysis and literature research.

Chapter 3 covers the noise prediction methodology. Within the study's scope, it is neither practical nor feasible to measure every hospital, school, and public health facility to determine the external and internal noise levels; rather a prediction methodology based on wall construction was used. To insure that the noise prediction methodology is accurate, a number of sample measurements was taken to correlate predicted and measured values. Included are the calculated noise reductions for schools, hospitals, and public health facilities located around Los Angeles International Airport, Stapleton Airport, Sky Harbor Airport, Logan International Airport, Miami International Airport, and William B. Hartsfield Airport.

Chapter 4 provides the techniques and methodology of noise measurement. Included is a technical discussion of the equipment and procedures for measuring noise levels. Architectural and engineering building investigation methods are also discussed.

Chapter 5 discusses the soundproofing techniques that are appropriate and feasible for modifying schools and hospitals. Rehabilitation principles and applications are defined.

Chapter 6 is devoted to developing the architectural and cost estimates of soundproofing, determining a cost and costing methodology, quantifying benefits, and developing priority funding requirements. Architectural estimates involve the determination of just what modifications can be made to a building and the limits that exist.

Costs of modifying sample buildings are discussed, and projections on a state, regional, and nationwide basis are presented. The costing methodology is outlined and explained.

Cost benefits are presented relative to the potential recovery of lost teaching time, lost student time, and energy conservation. The major benefit of soundproofing schools would be an improvement in the quality of classroom communications. The benefit of soundproofing hospitals and public health facilities would be an improvement in conditions associated with health care and patient recovery. These benefits have value, and the value has been quantified in terms of dollars.

Procedures and methods for determining priorities and criteria regarding decisions on the implementation of soundproofing for schools, hospitals, and public health facilities are provided.

Chapter 7 identifies, through procedural development, the state, regional, and nationwide impacts. Included is a determination of the number of schools, hospitals, and public health facilities impacted by aircraft noise; and the number of students and patients that are similarly impacted.

Chapter 8 covers a summary of the views and opinions expressed by local public officials regarding the concept of soundproofing as a means of alleviating the impact of aircraft noise. Findings reached by the contractors during the performance of this study are also included.

The appendices in this report contain detailed data as to the results obtained, the observed data, and the background of techniques used in the measurement and analysis. The data relative to threshold levels, exterior wall rating (EWR), calculated and predicted noise reduction are presented. Cost details including correction factors, costs per delta noise reduction, costs of sample buildings, and overall program costs are also included. In addition, a listing of people who offered views and opinions is provided.

CHAPTER 2

DETERMINATION OF THRESHOLD LEVELS

The objectives of this study required that threshold levels be established for noise effects on people in public buildings around airports. Since aircraft noise levels ordinarily encountered in buildings do not present a hearing-loss hazard to the building occupants, the threshold levels developed in this chapter were derived in terms of avoiding interference with noise-sensitive activity.

2.1 Application and Definition of Threshold Levels

Noise exposure in public buildings due to aircraft operations covers an extensive range of levels. To provide a lower bound for defining the magnitude of noise impact and projecting the application of soundproofing requirements, it was necessary to identify appropriate noise threshold levels. The noise thresholds identified in this study should not, however, be taken as acoustic criteria or specifications which define building noise attenuation requirements. The establishment of such standards requires a more thorough characterization of the building interior noise environment.

An illustration of the application of these threshold levels is shown in Figure 2-1.

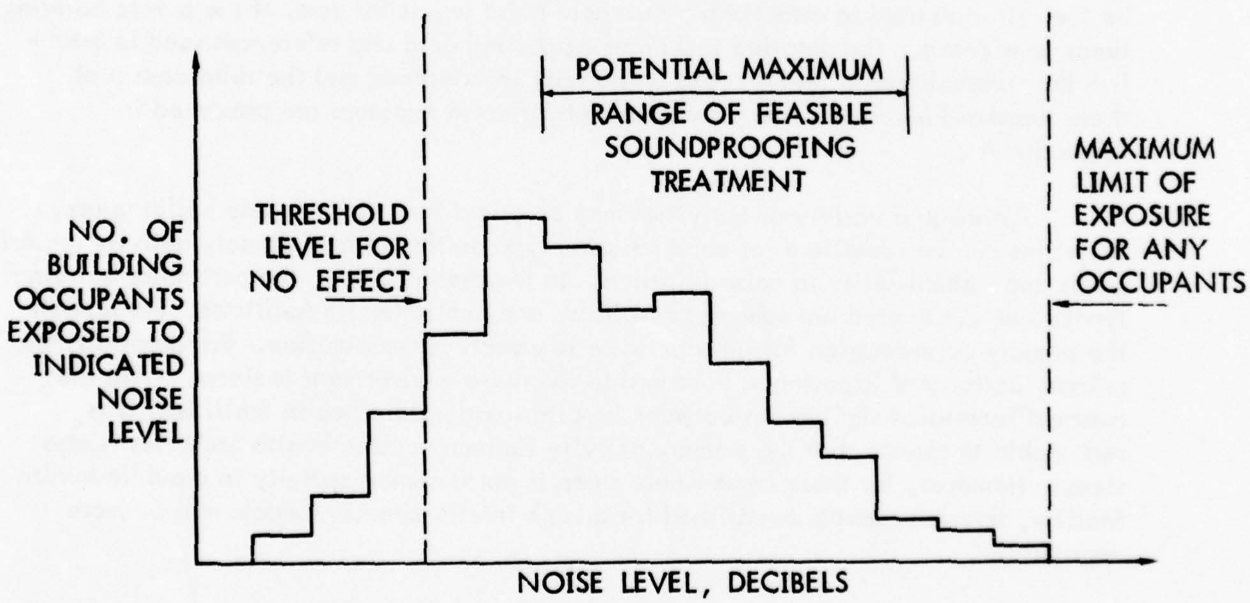

FIGURE 2-1. HYPOTHETICAL HISTOGRAM OF AIRCRAFT NOISE EXPOSURE FOR ALL OCCUPANTS WITHIN PUBLIC BUILDINGS INSIDE NEF 30 CONTOURS AROUND AIRPORTS. THIS ILLUSTRATES HOW THRESHOLD LEVELS FOR NOISE EFFECTS ON OCCUPANTS WILL ESTABLISH LOWER BOUND FOR EVALUATION OF FEASIBLE SOUNDPROOFING.

As shown, the threshold levels would establish a lower bound for application of feasible soundproofing measures. As indicated in the figure, it is anticipated that the maximum feasible range for soundproofing will be less than the total range between the threshold levels and the maximum limit of exposure. Thus, accurate definition of these threshold levels is clearly of paramount importance in establishing what portion of the occupants in public buildings exposed to levels above the threshold levels could benefit from feasible soundproofing.

The noise metric used in this study to express threshold level is the maximum A-weighted noise level in decibels (or for short, dBA) of an individual aircraft noise event. This choice of metric allows the data developed in the study to be expressed in a fundamental format, readily adaptable for use in comparing the relative costs of soundproofing.

2.2 Effects of Noise Pertinent For Establishing Threshold Levels

The adverse effects of noise exposure on people can be grouped into three general categories: degradation of health, attitudinal reactions, and activity interference. In general, the noise levels defining the threshold of interference with certain noise-sensitive activities (i.e., sleep and speech) are lower than those associated with the other two categories of adverse effects. For this reason, activity interference will be the criterion used in establishing threshold noise levels for each of the public building types considered. The detailed technical supporting data and references used to establish the threshold noise levels based on activity interference and the relationship of these threshold levels to other adverse effects of noise exposure are presented in Appendix A.

Although a variety of activities may be associated with any one building use, activities can be identified for each building type on the basis of primary activity requirements and susceptibility to noise intrusion. In the present study, the particular building types to be considered are schools, hospitals, and public health facilities. For schools, the primary consideration for interior noise is speech communication. For hospitals, the primary activity of importance in regard to the noise environment is sleep. With the assumed functional similarities between hospitals and public health facilities, it is reasonable to assume that the primary activity for many public health facilities is also sleep. However, for those cases where sleep is not a normal activity in a public health facility, threshold levels established for speech interference in schools will be more appropriate.

Based on the considerations described above, a literature review was conducted to determine those noise levels below which interference with the activities of speech and sleep would not occur. The results of this review, presented in Appendix A, are summarized in the following two sections with particular attention given to their application to schools and hospitals exposed to aircraft noise. Based on the results of this review, threshold noise levels for the onset of activity interference are estimated.

2.3 Threshold Levels For Speech Interference

The aircraft noise transmitted to the interior of buildings will be considered a background noise capable of interfering with speech communication. Such interference is a function of several factors:

- Noise level and spectral content of the background noise at the listener's ear.
- Spectral characteristics and voice effort of the speaker.
- Propagation of the speaker's voice to the listener(s). For typical indoor communication, conducted without the aid of any amplification, this propagation depends upon the separation distance between the speaker and listener(s) and the reverberation in the room.

For speech communication in a classroom situation, at least two additional factors are also pertinent:

- A noise environment which is conducive to learning is required. (For example, repeated short-term disruptions of speech communication can degrade the efficient flow of verbal instruction and lessons.)
- Children are not as familiar as adults with language and, therefore, according to studies identified in Appendix A, should have lower background noise levels to achieve the same degree of speech comprehension as adults.

Considering all these factors, the following procedure was used to make an estimate of the threshold level for speech communication in school buildings.

- Representative aircraft background noise levels were predicted for locations inside a school classroom. These levels were based on extensive data on outdoor aircraft noise spectra and outdoor-indoor noise reduction values of buildings in Wyle's files.
- Published data on the level and spectrum of a female voice using a raised vocal effort was used to estimate the speech level at a conservative distance of 9m (29.5 ft) from the speaker. (Based on the acoustic reverberation measurements conducted in school classrooms for this program, this separation was more than sufficient to place the listener in the reverberant sound field of the speaker's voice.)
- A standard method for predicting speech communication efficiency, based on use of a quantity called the Articulation Index (AI), was employed to predict the amount of speech interference for various levels of aircraft noise inside the hypothetical classroom.

The results of this analysis, described in more detail in Appendix A, are summarized in Figure 2-2. This illustrates how AI increases as the background noise level decreases. As indicated by the insert in the figure, the Articulation Index (AI) is a measure of the "area" in a plane of sound level, in decibels, and frequency where the latter is plotted on an empirical scale of frequency increments equally important to speech communication.

From this more abstract measure of speech communication efficiency, it is possible to predict the intelligibility of complete sentences as a more direct measure of communication effectiveness. For an AI of 0.98, studies identified in Appendix A show that 100 percent intelligibility of first-presented sentences and 98.6 percent correct identification from a list of 1,000 Phonetically Balanced (PB) words is obtained for adults. This latter test of speech communication is considered a conservative indicator for the threshold of onset of speech interference in schools.

As indicated in Figure 2-2, an AI of 0.98 is obtained when the background noise level is 45 dBA in the classroom situation considered in this analysis. Further reduction of the background noise level would produce no substantial increase in AI or in sentence intelligibility. Therefore, a level of 45 dBA due to intrusion of aircraft noise inside school buildings is selected as the threshold level for onset of speech interference effects in such buildings. This threshold level is considered a conservative figure suitable for application to this study and is shown, in Appendix A, to be consistent with other suggested limits, published in the literature, for background noise levels in school rooms.

Finally, it is desirable to examine the sensitivity of changes in speech communication to changes in the threshold limit. Table 2-1 summarizes these for values of threshold limit of 50 dBA and 55 dBA.

TABLE 2-1. SPEECH COMMUNICATION MEASURES AT THREE LEVELS OF BACKGROUND NOISE IN SCHOOLS

Background Noise Level, dBA	AI	% Intelligibility of First-Presented Sentences	% Correct Responses 1,000 PB Words
45	0.98	100	98.6
50	0.83	99.4	95
55	0.67	98.6	87.5

Considering 95 percent correct response by adults on the 1,000 PB word test as a conservative upper bound to a threshold limit for speech communication, the choice of 45 dBA has, at most, a 5 dB safety margin. This small safety margin is considered necessary for application in schools for the reasons cited earlier where speech communication with children is critical to the education process.

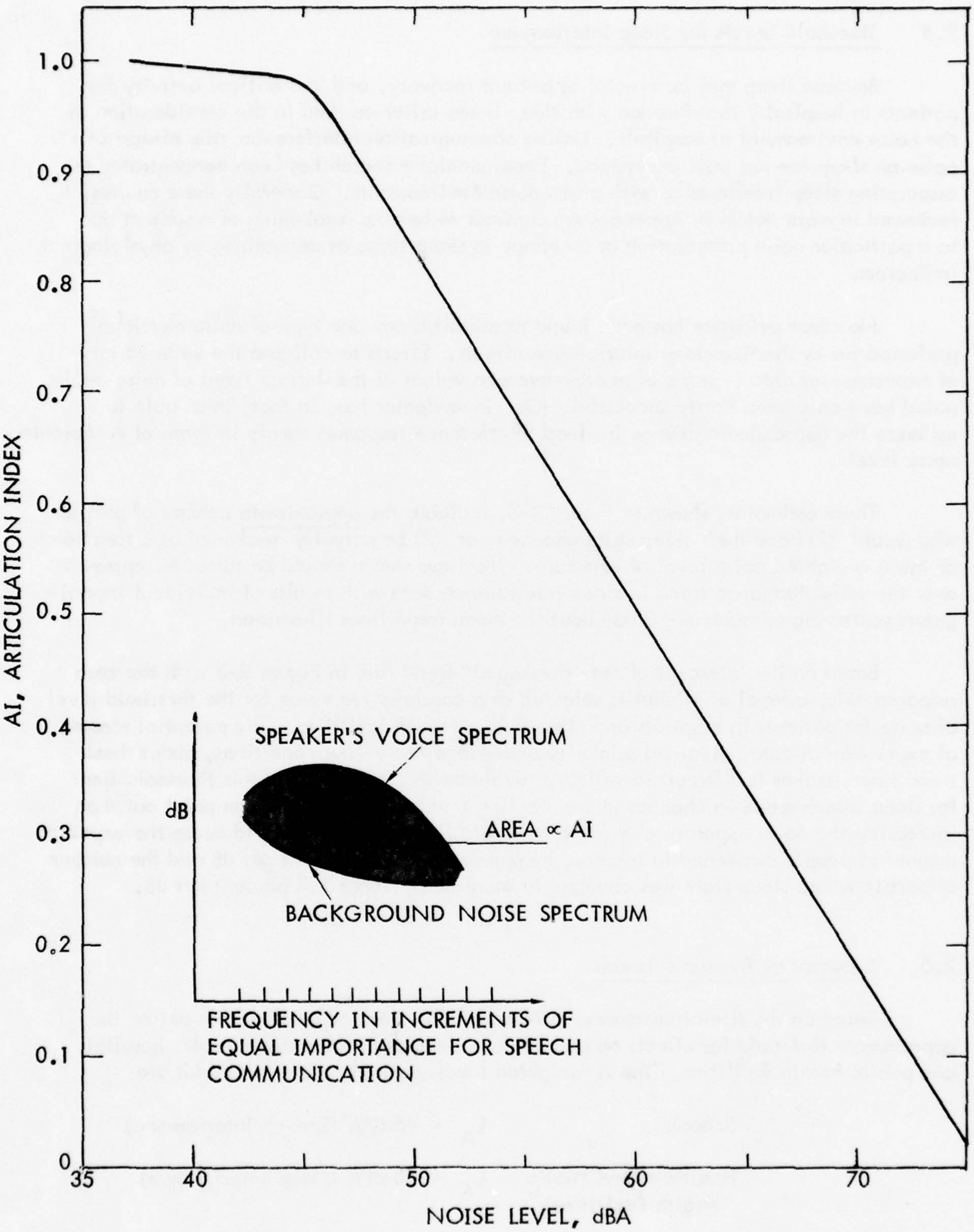

FIGURE 2-2. CHANGE IN ARTICULATION INDEX FOR TYPICAL CLASSROOM SPEECH COMMUNICATION AS A FUNCTION OF BACKGROUND NOISE LEVELS DUE TO AIRCRAFT.

2.4 Threshold Levels for Sleep Interference

Because sleep may be crucial to patient recovery, and is a critical activity for patients in hospitals, interference with sleep is the criterion used in the consideration of the noise environment of hospitals. Unlike communication interference, the effects of noise on sleep are not well understood. Experimental research has been concentrated on associating sleep interference with given noise environments. Generally these studies, reviewed in more detail in Appendix A, consider either the awakening of a subject due to a particular noise presentation or a change in sleep stage as determined by physiological indicators.

No clear evidence has been found to establish any one type of noise metric as preferred for evaluating sleep interference effects. Efforts to collapse the wide variety of experimental data in terms of energy-average values of the various types of noise evaluated have only been partly successful. One investigator has, in fact, been able to estimate the approximate change in sleep interference responses simply in terms of A-weighted noise levels.

These estimates, shown in Figure 2-3, indicate the approximate number of people who would (1) have their sleep state changed, or (2) be actually awakened as a function of the A-weighted noise level of exposure. The lines shown should be taken to represent only the estimated mean trend in sleep interference data with results of individual investigators scattering as much as ± 9 dB about the mean trend lines illustrated.

Based on the intercept of the "awakened" trend line in Figure 2-3 with the zero response axis, a level of 40 dBA is selected as a conservative value for the threshold level of noise for patients in hospitals and other public health facilities. The potential scatter of experimental data, obtained primarily under laboratory-like conditions, about these trend lines, makes it difficult to reliably evaluate the sensitivity of this threshold limit for sleep interference to changes in the limiting level. At best, one can point out that increasing the noise exposure above the threshold limit of 40 dBA would cause the expected number of people awakened to increase by approximately 1 percent per dB and the number of people whose sleep state was changed to increase by about 1.3 percent per dB.

2.5 Summary of Threshold Levels

Based on the literature review in Appendix A, interior levels which define the approximate threshold for effects on people have been established for schools, hospitals and public health facilities. The A-weighted levels defining these thresholds are:

Schools	L_A	= 45 dBA (Speech Interference)
Hospitals (and Public Health Facilities)	L_A	= 40 dBA (Sleep Interference)

Noise exposure to levels below these is not expected to produce any interference effects on people. While lower levels have been suggested by others, it is believed that the above levels represent realistic measures of the desired thresholds which are supported by the literature.

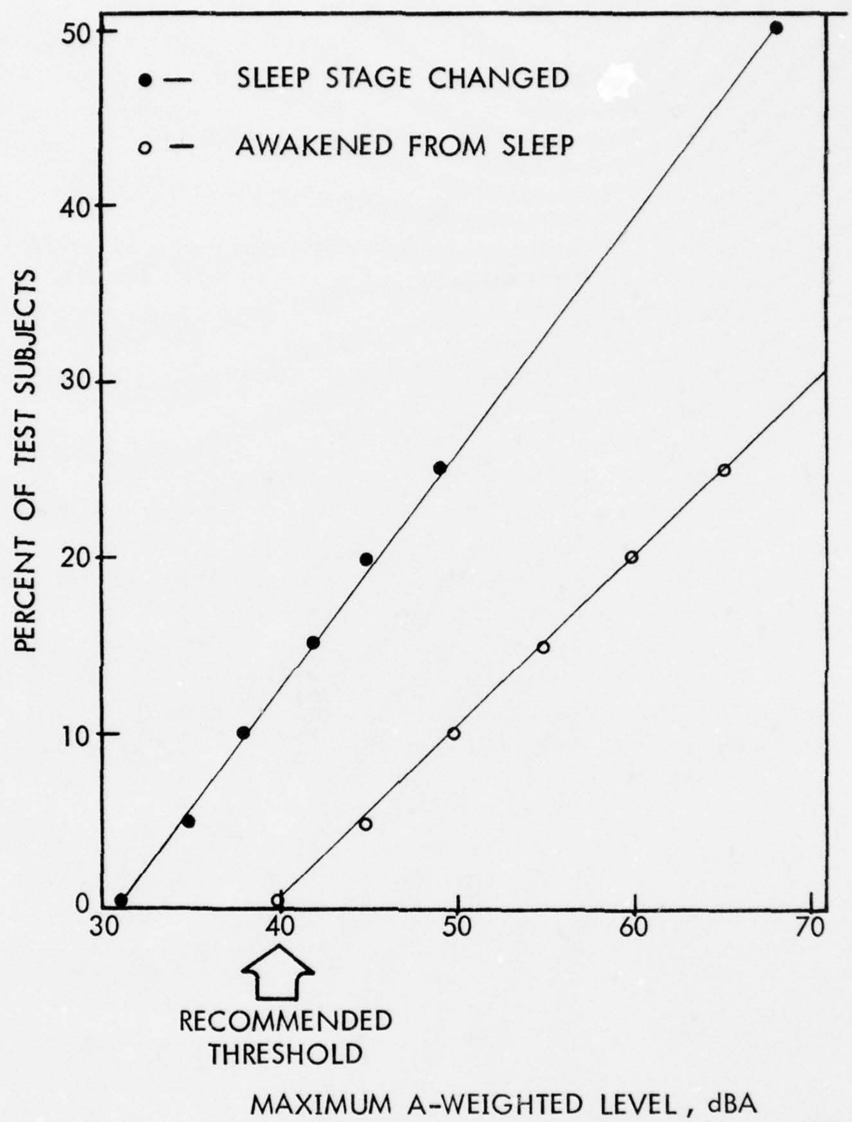

FIGURE 2-3. COMPOSITE OF LABORATORY DATA FOR SLEEP INTERFERENCE VERSUS MAXIMUM A-WEIGHTED NOISE LEVEL

CHAPTER 3

NOISE ATTENUATION OF BUILDINGS

The objectives of this project required the use of calculation procedures to determine the noise reduction of a building, and to determine the exterior noise environment around airports. The noise reduction calculation methodology is needed to predict both existing noise reduction and as a tool to identify needed modifications for improved noise reduction. The exterior noise prediction, when combined with building noise reduction, provides the interior noise environment to which occupants are exposed.

The reduction of noise by buildings, and the calculation procedures used in this study, are discussed in Section 3.1. The aircraft noise prediction method used, which provides maximum A-weighted noise levels for a median flyover event, is described in Section 3.2. Section 3.3 describes the application of these calculation methods to sixty study buildings located around six major hub airports.

3.1 Prediction of Building Noise Reduction

The noise level inside a room is determined by a balance between noise sources and losses. For buildings impacted by external noise, the noise source is the sound transmitted through the building structure. Losses are due to absorption of sound by interior surfaces. Noise reduction (NR) is the difference between the exterior noise level and the interior noise level due to the exterior noise.

In most cases, exterior sound is transmitted through a number of paths. These consist of airborne paths, such as open windows and vents, and structure-borne paths where the exterior noise causes structural elements (such as walls and window panes) to vibrate. These vibrating elements in turn radiate sound into the interior.

Transmission of sound by airborne paths is straightforward. Except for slight losses due to diffraction and interference effects at the edges, all the sound incident on an opening is transmitted. In most cases, this transmission is nearly independent of frequency. The transmitted sound is proportional to the open area, and has a spectrum similar to that of the exterior sound.

Structure-borne sound transmission is more complex. Only a fraction of the sound is transmitted. The remainder is either reflected or absorbed by the structure. Additionally, because the vibration properties of the structure are involved, transmission is generally frequency dependent. The fraction of sound energy transmitted is proportional to the area of the transmitting element times a frequency-dependent transmission coefficient. In general, the spectrum of the interior noise is different from that of the exterior noise.

After sound enters a room, a diffuse reverberant sound field builds up as it is repeatedly reflected from walls and other interior objects. At each reflection, some sound is absorbed so that a steady level is quickly achieved. This level represents a balance between transmission into the room and absorption by interior surfaces.

Transmission and absorption properties are generally frequency dependent, and the usual procedure is to compute noise reduction in several frequency bands. This noise reduction, usually expressed in decibels, is a property of the building and (with reasonable limits) is independent of the amplitude or frequency of the external noise.

If noise reduction is to be expressed in terms of the reduction of a single noise metric which combines several frequency bands (such as the overall or A-weighted noise level), then noise reduction is no longer a property of the building alone. It is also a function of both the exterior noise spectrum and the frequency weighting network to be used.

In the present project, the desired quantity is the interior A-weighted noise level due to aircraft noise, given the exterior A-weighted aircraft noise level. Within this report, the difference between these A-weighted levels will be called simply noise reduction or NR and is in units of decibels (dB).

If a single type of noise source is of interest, with spectra which do not vary greatly from event to event, then the noise reduction can again be defined as a property of the building for an average spectrum. In Appendix B, the concept of a single number transmission loss (as opposed to the usual frequency-dependent curve) is discussed in detail. Basically, if noise reduction of A-weighted noise of a given spectrum is desired, then it is possible to approximate the full transmission loss curve for a given structure by a single number. Calculation of noise reduction of a building may then be done with one set of values, rather than for each frequency band. This single number index of noise reduction in A-weighted sound levels, called the External Wall Rating (EWR), was developed initially for application to noise reduction through structures of highway noise. Highway noise was chosen as the basis because it is the single most prevalent outdoor noise source. EWR was also found to work well for aircraft noise spectra, but with slightly less accuracy than for highway noise. Tables of EWR for common construction are presented in Appendix B following the presentation of the background behind EWR and a brief comparison with another single number measure of transmission loss called Sound Transmission Class (STC).

The noise reduction calculations performed in the present project used the EWR method and EWR values presented in Appendix B. Room absorption values used in the calculations were based on measurements described in Chapter 4. The validity of using the EWR calculation procedure was demonstrated by comparing calculated noise reductions with measurements as described in Chapter 4.

3.2 Prediction of Noise From Aircraft Operations

The noise reduction calculation described above provides the link from exterior noise to interior. To complete the calculation of noise impact, exterior noise levels are needed. In this project, aircraft noise exposure is treated in terms of maximum A-weighted levels. Contours of maximum A-weighted noise levels for jet aircraft were therefore utilized for initial evaluation of the aircraft environments. However, it was recognized at the beginning of this program that a simplified noise prediction method was required in lieu of a complex one that might predict the very wide spread in maximum noise levels (standard deviations on the order of 5 to 8 dB) that one can expect at any single observation point on the ground near airports.

3.2.1 Commercial Jets

Based on consideration of the number of aircraft of various types, and similarity of number and type of engines, the majority of the U.S. commercial aircraft fleet may be considered to be comprised of the following five basic types:

- 2-Engine Narrow Body (DC-9, B-737, BAC-111)
- 3-Engine Narrow Body (B-727)
- 4-Engine Narrow Body (B-707, DC-8)
- 3-Engine Wide Body (DC-10, L-1011)
- 4-Engine Wide Body (B-747)

The maximum noise level for each of these aircraft types is a function of engine thrust setting, distance from observer to the point of nearest approach, and atmospheric conditions. Noise levels as a function of distance and thrust setting, at sea level and 15°C, are available from noise data contained in Reference 3-1. Most of the data are based on actual flyover measurements conducted by the manufacturer, and are the data collected by the FAA in the Aircraft Noise Definition (AND) studies; specific sources are documented in Reference 3-1. Figure 3-1 shows the maximum A-weighted noise levels for these five aircraft types as a function of slant range to the flight track at take-off power and at landing power.

Noise contours depend on the altitude and thrust of the aircraft as a function of distance from brake release on take-off and touchdown point for landings. Take-off noise contours were constructed based on the following conditions:

- Aircraft gross weight was assumed to be that for a medium-range flight for that aircraft type.
- Standard ATA take-off procedure using take-off power from brake release to 1500' altitude, then cutback to climb power, was assumed.

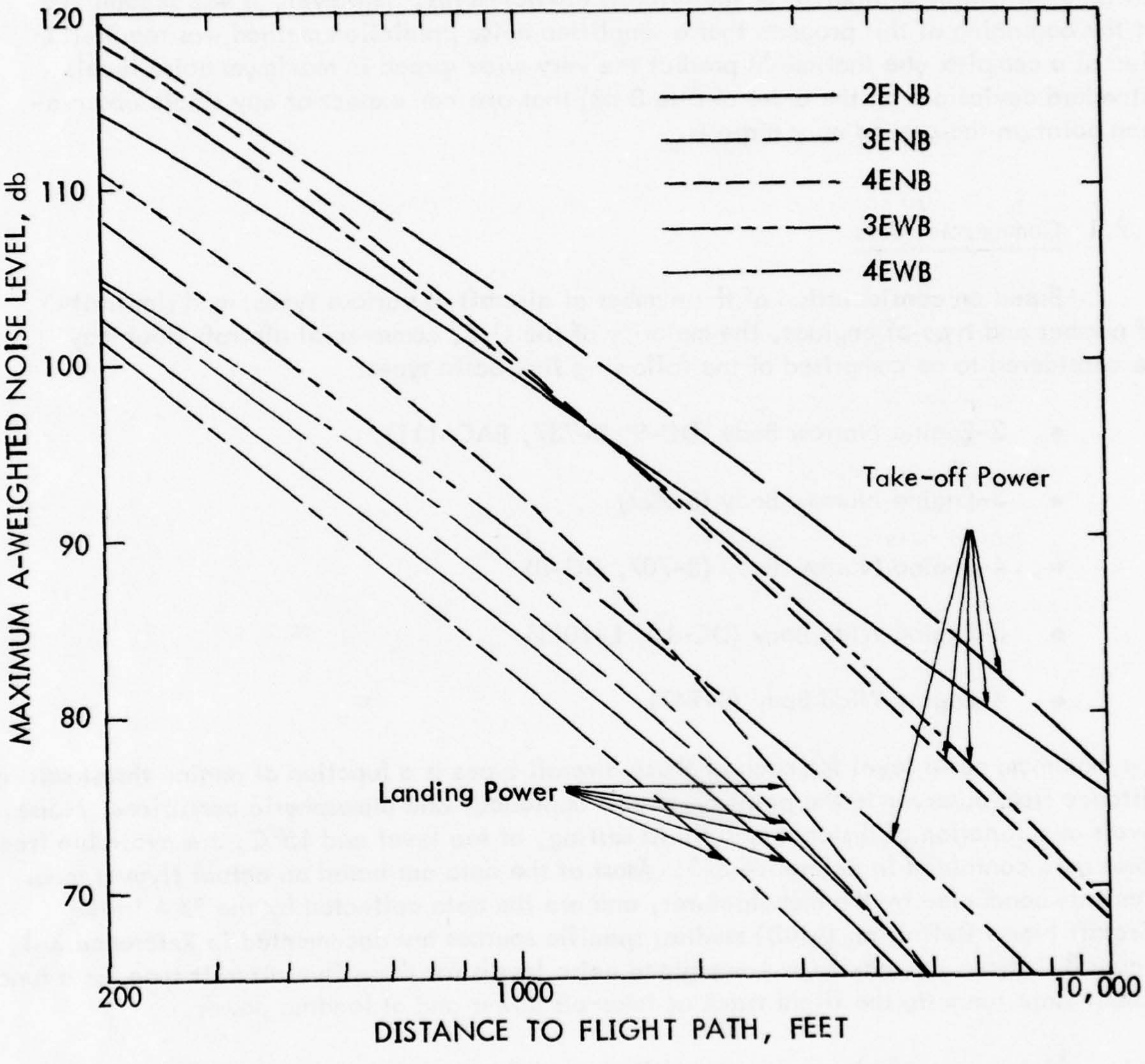

FIGURE 3-1. NOISE LEVELS FOR COMMERCIAL JET AIRCRAFT

- Constant climb angle, based on aircraft performance, was assumed at each power setting.

- For elevation angles of less than 10^{o} from observer point to aircraft, the noise levels were adjusted for excess ground attenuation (EGA) using the same method as in Reference 3-1.*

Landing noise contours were constructed for the following conditions:

- 3^{o} glide slope.

- Landing flap setting.

- Thrust setting corresponding to the glide slope and flap setting.

Contours were constructed for sea level only. Thrust reversal after touchdown was not considered because it is assumed that take-offs will occur on the same runway; take-off noise level is generally higher than landing thrust reversal.

The contours were constructed at 5 dB intervals from 110 dBA to 65 dBA. In most cases, contour levels less than 75 dBA involved trajectory elements where aircraft altitude exceeded 3,000 feet ontake-off, so that the assumed climb angle may no longer be correct. In some cases the noise levels were extrapolated beyond a slant range of 10,000 feet, the limit of the basic noise curves. Constructing noise contours out this far was necessary in order to be consistent with the threshold noise levels and calculated noise reductions discussed earlier. Beyond the point where aircraft achieve a 3,000-foot altitude, the contours must be considered to provide nominal values only. Because aircraft do not follow standard thrust and climb procedures at these distances, it is not felt that more precise values could be developed.

The maximum noise levels for each aircraft type in themselves do not provide a useful description of the noise environment. Fleet size and mix considerations would also have to be considered. Within the context of the present study, where typical maximum single event noise levels are desired, the median maximum level is required.

The U.S. commercial jet fleet (represented in terms of the five types noted above) was arranged in order of noise level based on the noise data of Figure 3-1. Total numbers of each type are from Reference 3-1.

The order of noise level differs for slant ranges less than 1,000 feet and greater than 2,000 feet on take-off,and for landings. The rank orders of aircraft by noise level for these three groupings are shown in Table 3-1, with the highest noise level at the top. Between 1,000 and 2,000 feet on takeoff, the maximum thrust noise levels for the three middle type of aircraft are within 2 dB of each other.

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* Recent data have been reputed to suggest excess ground attenuation may occur for aircraft elevation angles up to at least 30^{o}. However, the method used in this study for estimating EGA is consistent with Wyle experience in comparing measured and predicted aircraft noise levels in airport sideline areas where EGA is particularly significant.

TABLE 3-1. U.S. COMMERCIAL JET FLEET, RANKED BY MAXIMUM A-WEIGHTED NOISE LEVEL*

Take-off, Slant Range < 1,000'		Take-off, Slant Range > 2,000'		Landing	
Aircraft Type	Number	Aircraft Type	Number	Aircraft Type	Number
3ENB	687	3ENB	687	4ENB	738
4ENB	738	2ENB	546	4EWB	106
4EWB	106	4EWB	106	3ENB	687
2ENB	546	4ENB	738	2ENB	546
3EWB	80	3EWB	80	3EWB	80

* Aircraft with highest noise level listed on top.

At slant ranges greater than 2,000 feet, the take-off median is the two-engine narrow body. Between 1,000 and 2,000 feet, this would also serve as well as the other two middle aircraft. At less than 1,000 feet, the take-off median is the four engine narrow body. The median for landings is the three-engine narrow body.

Rather than use different aircraft for the three groups, the two-engine narrow body contour was used as the representative median aircraft type for purposes of this program. This is considered a reasonable choice for two additional reasons. The maximum noise levels of three- and four-engine narrow body jets will be reduced by the current retrofit program; current two-engine narrow body levels would be more representative of future fleet median levels. Also, Table 3-1 lists numbers of aircraft, not operations. Because two-engine narrow body jets are used on relatively short flights, they would be involved in a greater proportion of take-offs and landings, and thus would be closer to a median event than the fleet numbers indicate.

3.2.2 General Aviation Jets

At general aviation airports not served by commercial jets, typical noise levels may not be taken as commercial jet fleet median levels. As a first approximation, however, the commercial jet contours may be used together with suitable noise level adjustments. Table 3-2 lists these adjustments to be applied to the commercial jet contour for various general aviation jets. These values were obtained from direct measurements of noise from general aviation jets and DC-9 or B-737 overflights at the same locations around airports. The adjustments thus account approximately for observed noise levels on the ground due to both source noise level and flight profile differences between general aviation jets and DC-9/B-737 type aircraft. Source references are documented in Reference 3-2.

3.3 Prediction of Noise Reduction Around Six Major Airports

In order to obtain a data base of construction information pertinent to noise reduction, a field investigation was conducted. Six large hub airports in various geographic regions were chosen for study. At each airport, detailed construction and building-use information was collected for ten buildings. The construction information was used to compute existing noise reduction and as a basis for designing modifications to improve noise reductions. At three of the airports, measurements were made of existing noise reductions.

The selection of the study airports and buildings is described in Section 3.3.1. Section 3.3.2 contains a discussion of the kind of information gathered. Predicted noise reductions, using the EWR method, are discussed in Section 3.3.3.

TABLE 3-2. ADJUSTMENTS TO OBTAIN GENERAL AVIATION JET NOISE LEVELS FROM 2-ENGINE NARROW BODY MAXIMUM NOISE LEVEL CONTOURS

Aircraft Type	Gross Weight, lbs.	Adjustment (dB) Landing	Adjustment (dB) Takeoff
2-Engine Turbojet (Sabreliner, Lear Jet)	10 - 20,000	-5	0
2-Engine Turbofan (Dassault Falcon)	20 - 30,000	-5	-10
2-Engine Turbofan (Grumman Gulfstream)	30 - 60,000	0	0
2-Engine HBPR Turbofan (Cessna Citation)	10 - 20,000	-15	-15
4-Engine Turbojet (Lockheed Jetstar)	25 - 50,000	+3	+3

3.3.1 Selection of Study Buildings

One objective of this program was to develop a noise reduction data base on a national scale. This required the selection of buildings of a variety of construction types. Because construction practices can vary geographically, the approach taken was to select six study airports, each in a different geographical region, then select ten study buildings around each. The number of airports and buildings was determined by resource and schedule constraints of the program.

Geographical Regions of Similar Construction

It has been found that patterns of construction have established themselves in different areas of the country. Among the things which influence these patterns are climatic conditions, availability of materials, availability of labor, seismic zone, local historical construction trends, and local economic conditions. Figure 3-2 shows a map of the continental United States and the six regions of similar construction. A short description of each area is given below.

Region A: The Pacific Coastline. The climate is relatively mild as far inland as the Sierra Nevada foothills. Additionally, this area contains three major metropolitan sections: San Francisco-Oakland-San Jose complex, Los Angeles-Orange-Riverside-San Bernardino Counties complex, and the San Diego County area. The population concentration is relatively high, bringing with it the influx of skilled trades. Lumber is plentiful as are aggregates for concrete, and most all other standard building materials, explaining the proliferation of stud-and-stucco construction, modified by the higher cost systems such as brick veneers. The higher economic level of a metropolitan and industrial area permits use of more expensive methods and materials for aesthetic purposes. Seismicity for this area is high and is an important consideration.

Region B: Inland Southern California, Southern Nevada, and Southwestern Arizona. Climate is a prime factor; hot, dry summers and relatively mild winters. Closely spaced metropolitan areas do not exist. Lumber is imported, but sand and aggregates for concrete block are plentiful. Therefore, in this area building will have a greater percentage of concrete masonry. As a further incentive, concrete block structures are cool in the long summers. The common stud-and-stucco combination is also popular, as in this area it is again the most economical and durable. Additionally, maintenance is low for stucco in relation to wood, which needs paint more frequently.

Region C: The Gulf Coast and South Atlantic Coastline. This area enjoys a relatively mild climate with high humidity and is subject to violent tropical storms. Clay for brick is relatively abundant, as is local lumber. Therefore, less stud-and-stucco construction is used as it is more susceptible to moisture, and the brick and concrete block construction is more popular. When wood framing is used, it is often protected by brick veneer. Because of the high humidity and generous rainfall, concrete block is often protected by exterior plaster.

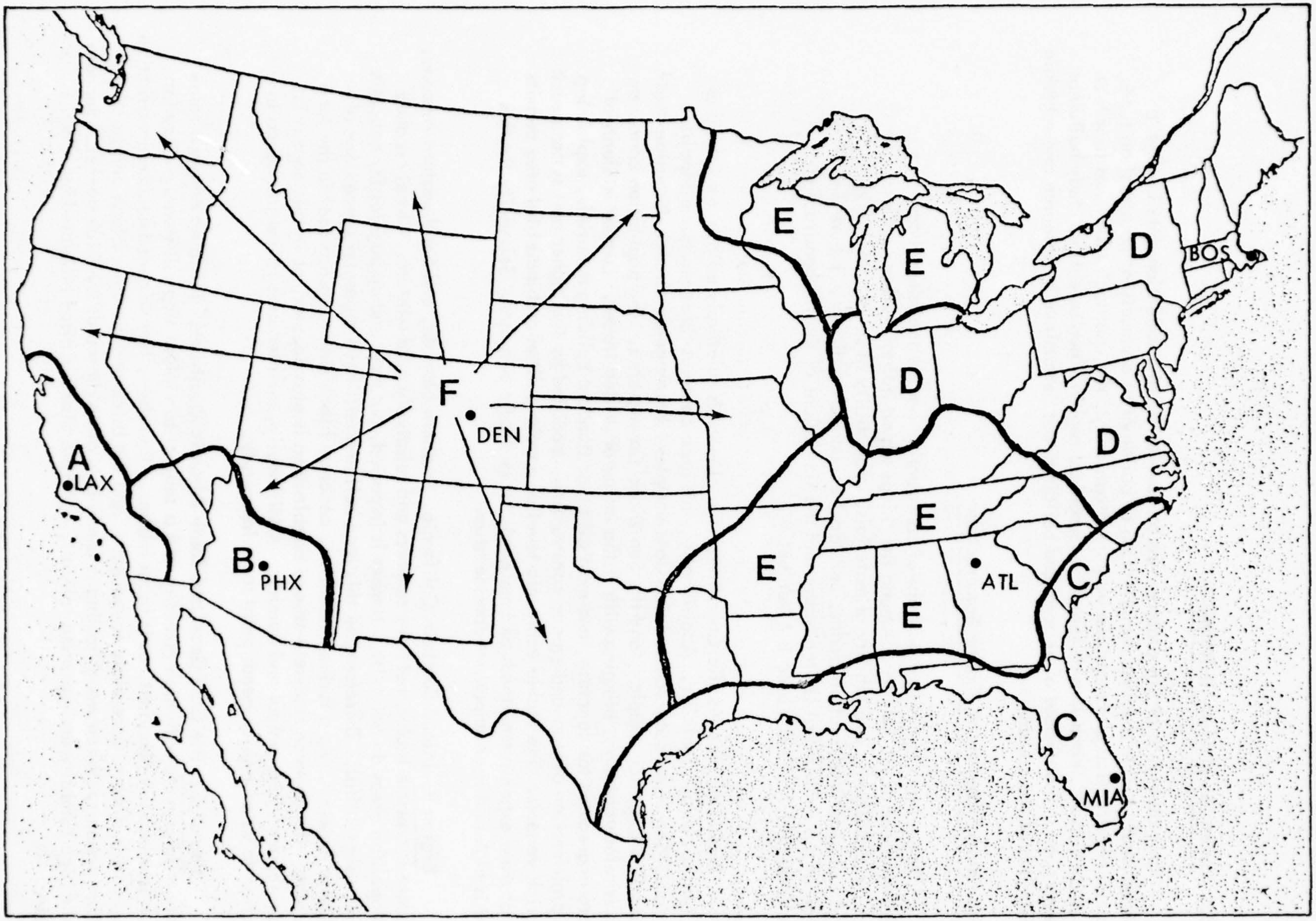

FIGURE 3-2. GEOGRAPHICAL AREAS OF DIFFERING CONSTRUCTION PRACTICES

Region D: Eastern Seaboard and Inland to Central Illinois. Both climate and concentration of population comprise the prime influence here. The climate is quite cold for half the year and insulation properties are important. Both brick clay and local lumber are available, and the labor availability in all trades is generally good.

Region E: Great Lakes (Western) States and Central South. Although these areas have considerably different climates, the average construction is similar due to economics. Lumber is local and plentiful, as is clay for brick.

Away from metropolitan areas, union influence is not so strong, and carpenters are frequently jacks-of-all-trades, laying brick and block, installing gypsumboard or plastering.

Region F: Central States. These areas of different climatic conditions are governed more by economics than by climate. All parts of this area experience below-freezing winters and hot, moderately humid summers. More important, however, is the commonality that, with the exception of very localized spots such as the Seattle-Tacoma area, there is no concentration of urbanization and industrialization; consequently, the economy of the area is the prime factor, and materials and construction combinations giving best insulation at least cost are predominant.

In this region, the carpenter is frequently the general builder. Material influences are again balanced between the easy transportability of lumber and the general local availability of clay for bricks. Thus, the construction norms for different parts of the area arrive at the same result from different reasons.

Basing geographical variation on the six regions shown in Figure 3-2, one major hub in each region was selected. These are:

- Region A Los Angeles International Airport (LAX)
- Region B Sky Harbor International Airport (PHX)
- Region C Miami International Airport (MIA)
- Region D Logan International Airport (BOS)
- Region E Hartsfield International Airport (ATL)
- Region F Stapleton International Airport (DEN)

Selection of Buildings

Around each airport, ten buildings were selected for detailed study. At most airports, eight buildings — considered to be noise impacted — were within the NEF 30 contour, while two non-impacted buildings were well outside the NEF 30 contour. The buildings were selected so as to represent a cross-section of building types. The criteria used for selecting the buildings were based on:

- Building design and construction
- Age
- Proximity to airport
- Exposure to noise environment

At each city, candidate buildings were first identified with respect to distance from the airport by reviewing topographic maps. Local school and hospital authorities were then contacted for permission to inspect the buildings. In most cases, the regional FAA office made introductory arrangements. Final selection was made on the basis of the criteria noted above.

3.3.2 Building-Use and Construction Information

The data collected for each building covered the following two areas:

- Size, use, and number of occupants
- Construction data required to predict noise reduction

Appendix C contains a worksheet used to record these data. The use information is self-explanatory. The construction data are those required to compute noise reduction by the method described in Appendix B.

Construction information was gathered by either a construction engineer or an architect. Visible features were noted from direct measurement. Where possible, building plans were examined to determine details not visible. Where plans were not available, details were estimated on the basis of known local construction practice. Appendix D contains a tabulated summary of building-use and construction data.

3.3.3 Calculated Noise Reduction

Noise reduction was calculated for each different type of room in each of the study buildings, using the EWR method. Appendix E contains tabulated values of all the steps in the calculation. These tables quantitatively show the relative importance of each structural component to the transmission of sound into the buildings.

The calculated existing noise reductions, grouped by geographical region and type of building, are discussed below.

Schools

Figures 3-3 and 3-4 summarize the noise reduction of classrooms. Figures 3-3a through 3-3f show the number of classrooms with various noise reduction in each region. Figure 3-4 shows all regions grouped together.

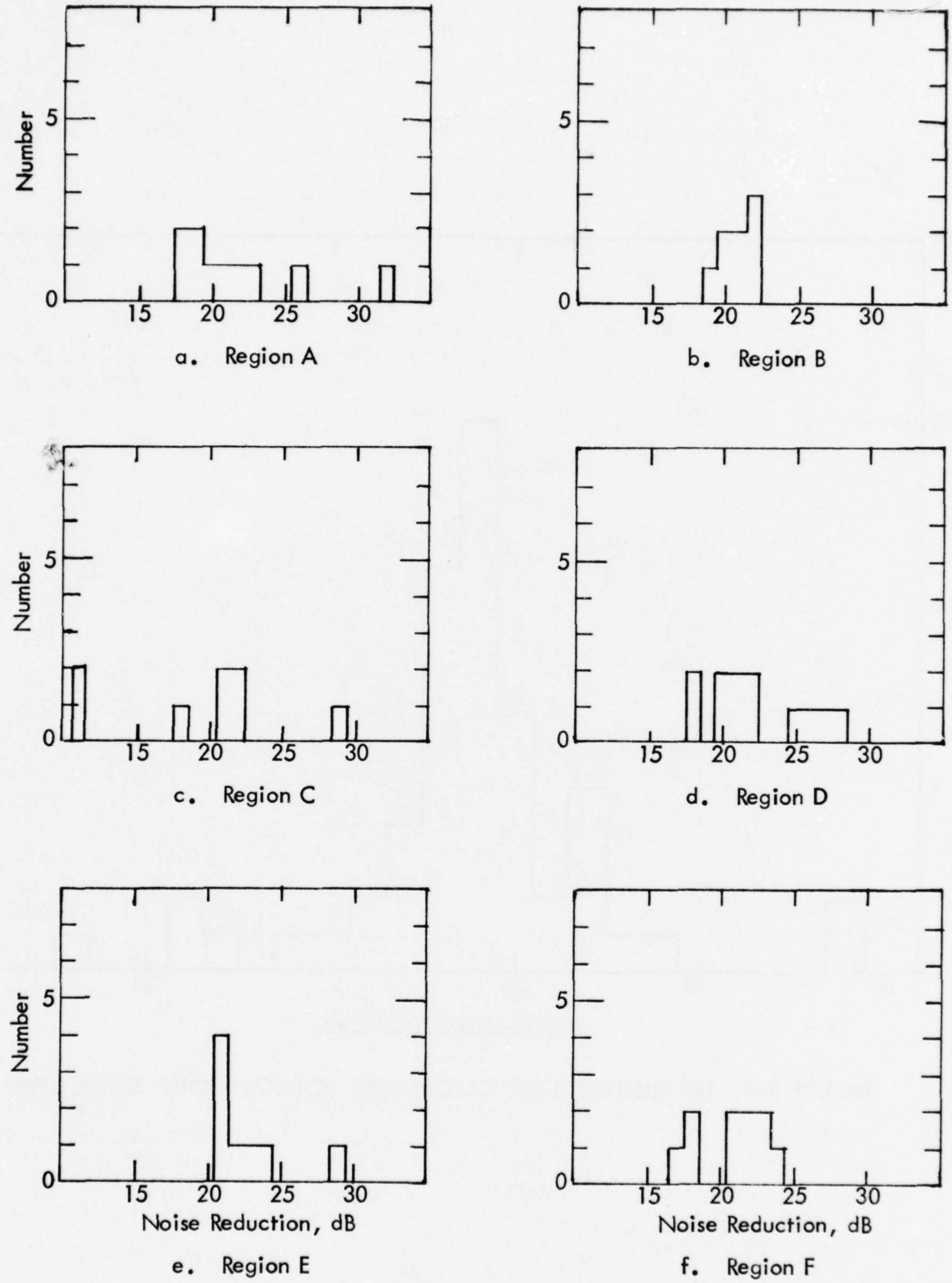

FIGURE 3-3. DISTRIBUTION OF CALCULATED SCHOOL NOISE REDUCTION, BY REGION

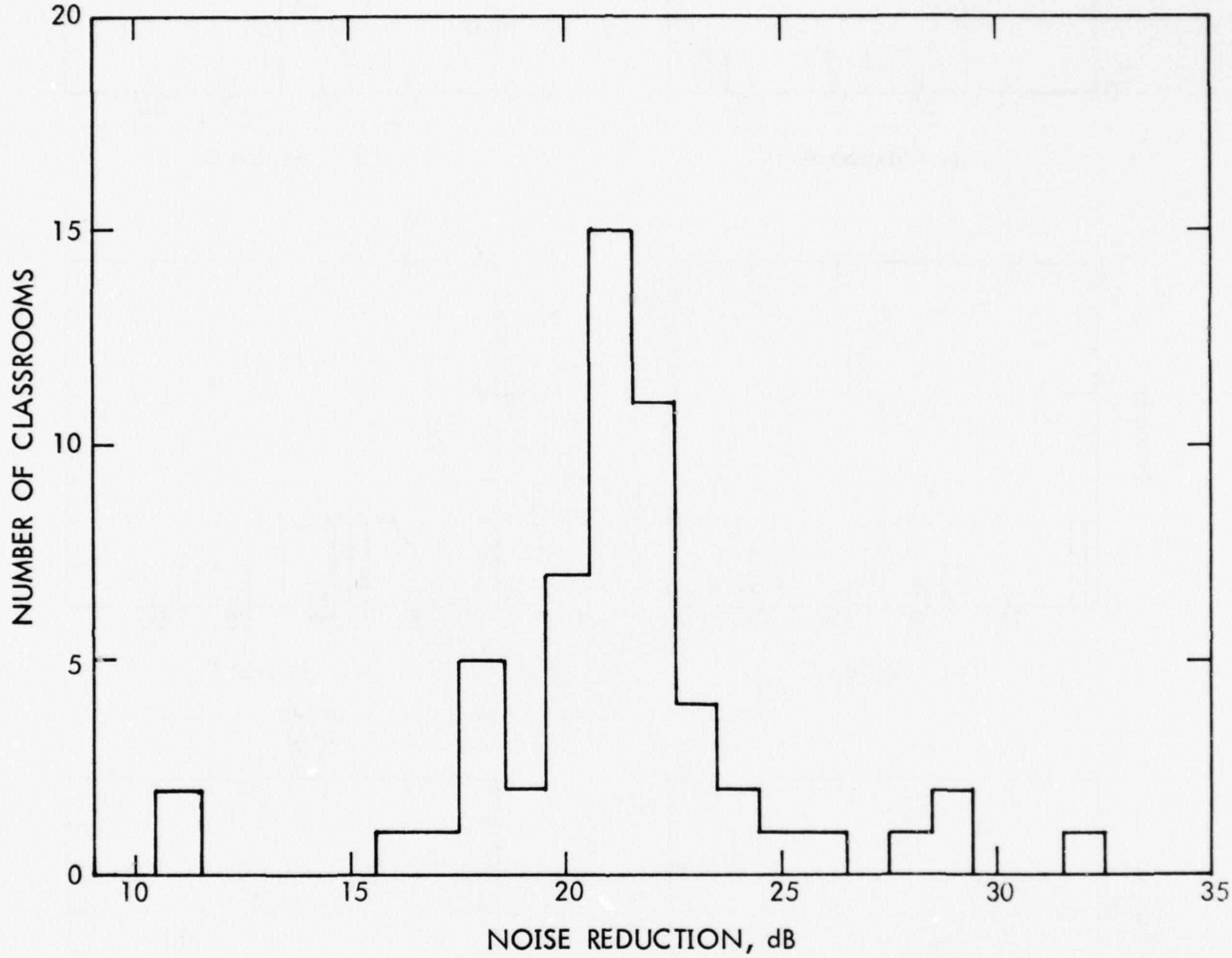

FIGURE 3-4. DISTRIBUTION OF CALCULATED SCHOOL NOISE REDUCTION

Except for Region C, school noise reductions fell into two groupings. Most fell in the range of 16 to 26 dB, with a consistent average of approximately 21 dB. These were traditional style classrooms with large areas of single-glazed windows. Most of the noise transmitted was through the windows. In some areas, exterior doors were important transmission paths, but rarely exceeded windows.

Approximately 10 percent of the buildings in all regions combined have noise reductions in the range 28-32 dB. These were either schools with unusually small windows or which had received some noise reduction treatment. One school had classrooms in which windows had been eliminated. The total sample size is not large enough to identify regional trends in this type of building.

Region C was similar to the other five regions except that two schools had large open vents, resulting in NR = 11.

Hospitals

Figures 3-5 and 3-6 summarize the noise reduction of hospitals. The sample size is too small to identify any regional trends. In one region (E) no hospitals were visited.

The national distribution, shown in Figure 3-6, is very nearly flat from 18 dB to 28 dB. This is apparently due to the heterogenous nature of hospital design, with window size varying greatly according to architectural style. In all cases windows were the greatest transmission path (see Appendix D), but window area exhibited no trends.

Although the total sample size of hospitals was not large, it is not expected that a larger sample would show any consistent trends not seen in Figure 3-6.

Regional Differences

Except for the two schools in Region C with open vents, no significant differences in existing noise reduction were found among the six regions. This is because windows were the main transmission path in most cases, and these did not vary geographically for the study buildings. Regional differences in construction can be important, however, when considering improving noise reduction, because transmission through other components then becomes significant. For example, in those regions where exterior doors are widely used, noise reduction improvement must include door modification.

Average Regional Values

For use in estimating the magnitude of the problem (see Chapter 7), average regional values of existing noise reduction are required. Based on Figures 3-3 through 3-6, the values used are:

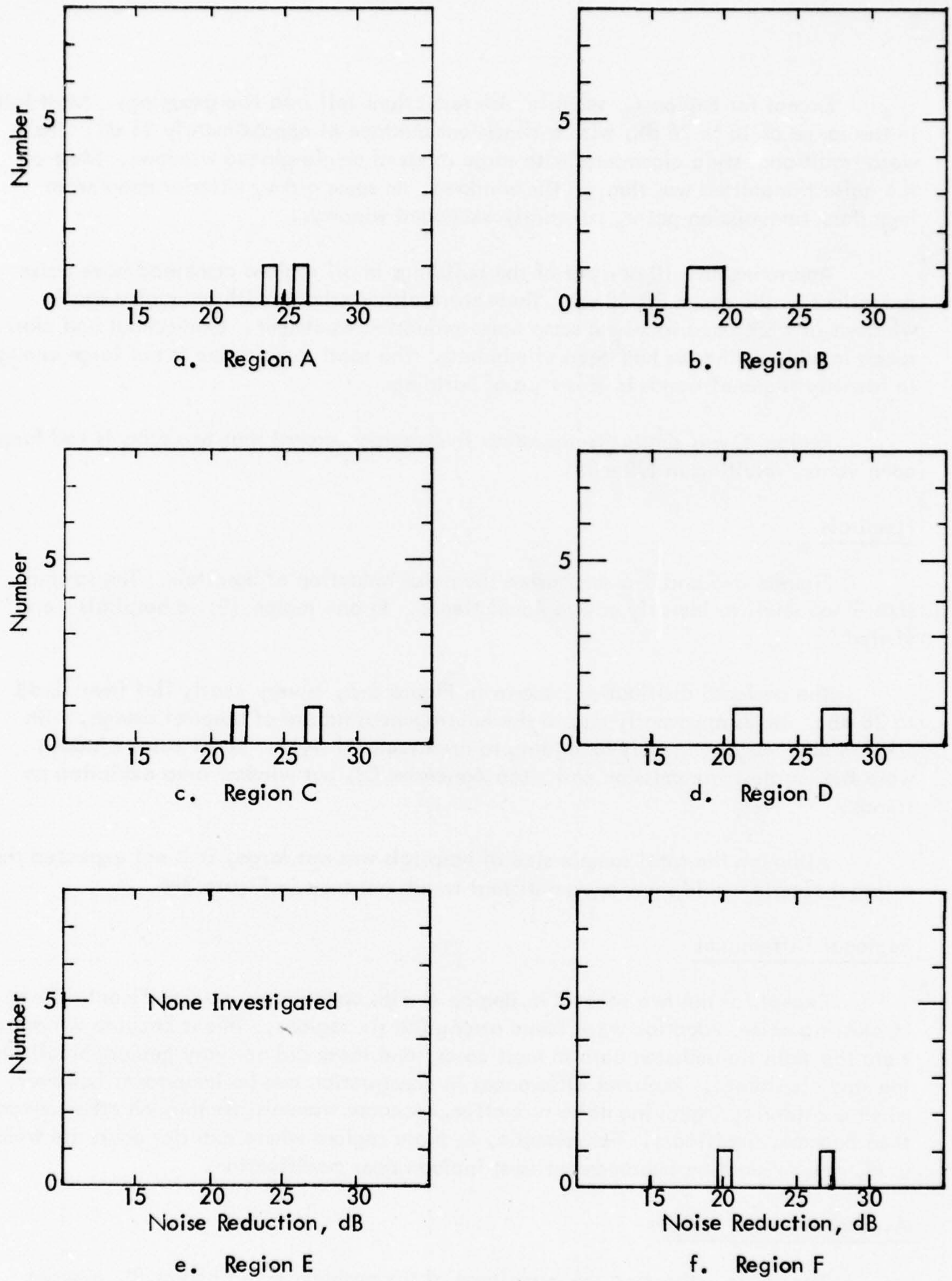

FIGURE 3-5. DISTRIBUTIONS OF CALCULATED HOSPITAL NOISE REDUCTION, BY REGION

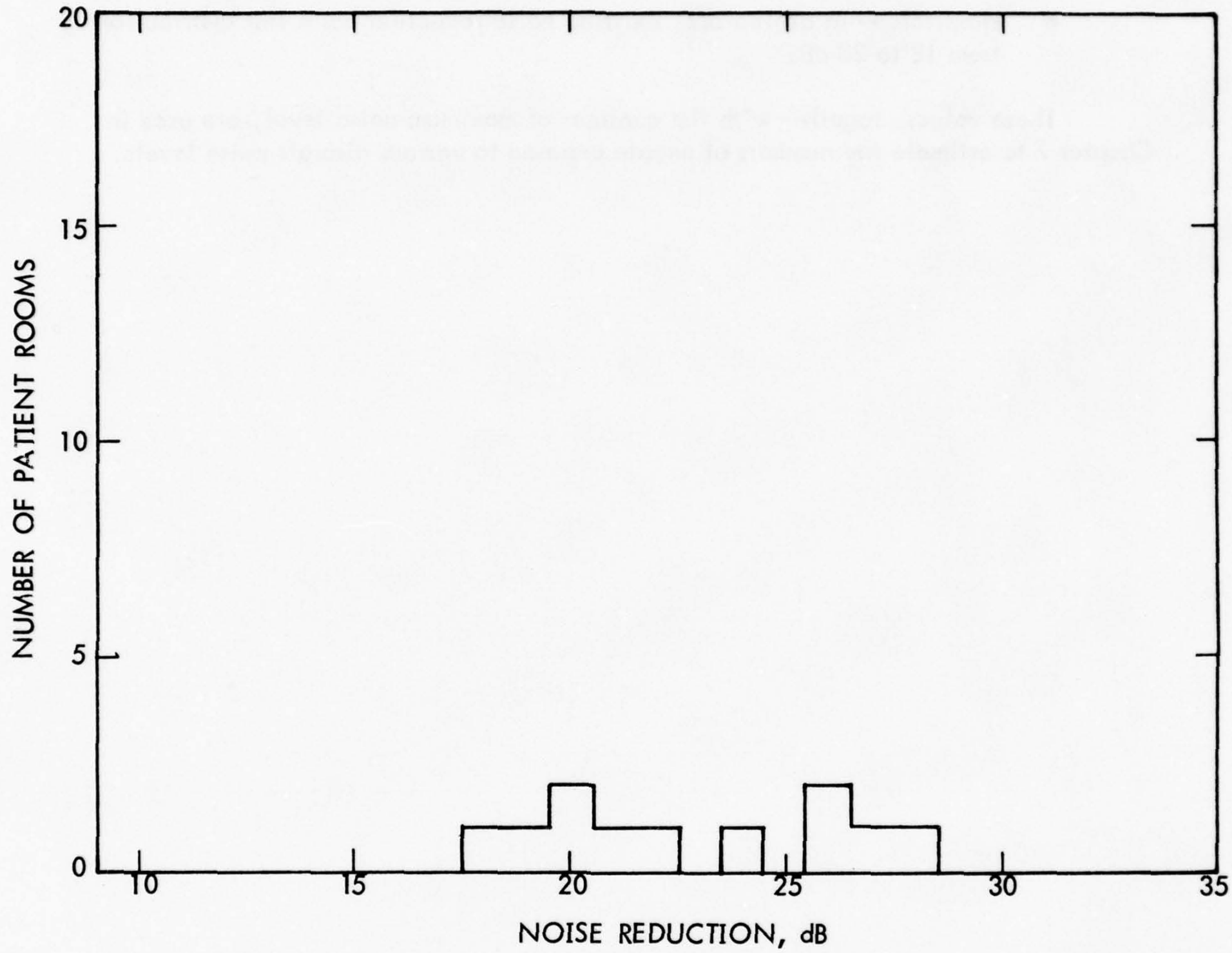

FIGURE 3-6. DISTRIBUTION OF CALCULATED HOSPITAL NOISE REDUCTION.

- Schools — in all regions except C, 90 percent of schools are estimated to have NR = 21 dB and 10 percent have NR = 29 dB. In Region C, 20 percent have NR = 11 dB, 60 percent have NR = 21 dB, and 10 percent have NR = 29 dB.

- Hospitals — in all regions, existing noise reduction has a flat distribution from 18 to 28 dB.

These values, together with the contours of maximum noise level, are used in Chapter 7 to estimate the numbers of people exposed to various aircraft noise levels.

REFERENCES — CHAPTER 3

3-1. Bartel, C., Sutherland, D.C., and Simpson, L., "Airport Noise Reduction Forecast: Volume I – Summary Report for 23 Airports", Wyle Research Report WCR 74-14-I, for the Department of Transportation, October 1974; also DOT-TST-75-3.

3-2. "Simplified Procedures for Estimating the Noise Impact Boundary for Small and Medium Size Airports in the State of California", Report to the California Department of Aeronautics, Wyle Laboratories Report No. WCR 72-3, May 1973.

CHAPTER 4

FIELD MEASUREMENTS AND INVESTIGATIONS

4.1 Purpose

A part of this study involves the prediction of the noise reduction for a sampling of schools, hospitals and public health facilities located near major airports, as described in Chapter 3. In relation to this effort the purpose of the field measurements was to:

1) Validate the building noise reduction prediction methodology, and

2) Provide data on the interior acoustic absorption characteristics of the building types of interest.

Determination of building noise reduction was accomplished by simultaneously recording the building interior and exterior noise levels produced by aircraft overflights. At least twelve aircraft events were recorded for each of the rooms under study. The building noise reduction was taken as the average of the difference between exterior and interior maximum noise levels over all events.

Noise reduction measurements were conducted at eight buildings around LAX, and seven buildings each around DEN and BOS. Interior absorption measurements were conducted in all study buildings around each of these three airports.

4.2 Measurement Procedures

4.2.1 Instrumentation

The instrumentation system used in this study consisted of a two-channel magnetic tape recorder equipped with two condenser microphones. A precision sound level meter was used for direct reading of noise levels, and also as an amplifier in one microphone channel. Specific equipment used, with pertinent operating characteristics, is given in Appendix E. The frequency response of each channel of the assembled system was tested by recording and playing back a pink noise signal. The system response was found to be flat to within ± 1 dB over a frequency range of 100 to 8000 Hz. In the field, 1000 Hz calibration tones were recorded before each set of measurements.

4.2.2 Building Noise Attenuation Measurements

Exterior Microphone Placement

In order to measure the noise at the room locations, the exterior microphone was placed directly on the exterior classroom wall. A wall facing the aircraft flight path was always used. In most cases this corresponded to the wall with the most window area. The microphone, together with its windscreen, was taped in place, so that the distance from the microphone cartridge to the wall was approximately $1\frac{1}{2}$ inches, the radius of the windscreen. No detectable difference in measured noise level was noted between positioning the microphone over window glass or external wall structure.

The wall mounting was used to avoid microscale variations in measured level due to local geometry and to avoid problems with interference patterns. The benefits are the same as in the current trend toward using ground-surface-mounted microphones rather than microphones a few feet above the ground.[4-1,4-2]

Due to noise reflection from the exterior walls, it was necessary to apply a correction factor from the measured exterior noise levels to express the noise data in terms of free-field values. For a flush-mounted microphone on a rigid wall this correction factor is a subtraction of 6 dB from the measured level to obtain the free-field level. In practice, due to the spacing of the microphone from the exterior wall surface coupled with sound scattering from ever-present surface irregularities, the actual correction to free-field is slightly less. From previous noise measurements taken at a variety of building surfaces it was determined that a correction of approximately 5 dB provided the most realistic estimate for typical building exterior surfaces. The use of a 5 dB correction was additionally verified by comparing surface-mounted and free-field noise measurements taken at the initial building studied in the field investigation.

Interior Microphone and NR Measurement

Interior noise measurements were made at four locations within each room. Figure 4-1 shows the arrangement of interior and exterior microphones. The interior microphone points are at locations dividing the room dimensions into thirds. Three flyover events were recorded with the interior microphone at each location shown, for a total of twelve events. At two points the microphone was at a height of 1/3 the floor-to-ceiling distance; at the other two it was 2/3. Inside and outside data were recorded simultaneously on the two-channel recorder. Calibration tones were recorded before each set of twelve. These measurements were subsequently reduced by A-weighting and displaying on a graphic-level recorder. Maximum A-weighted levels were obtained from the graphic-level recorder charts.

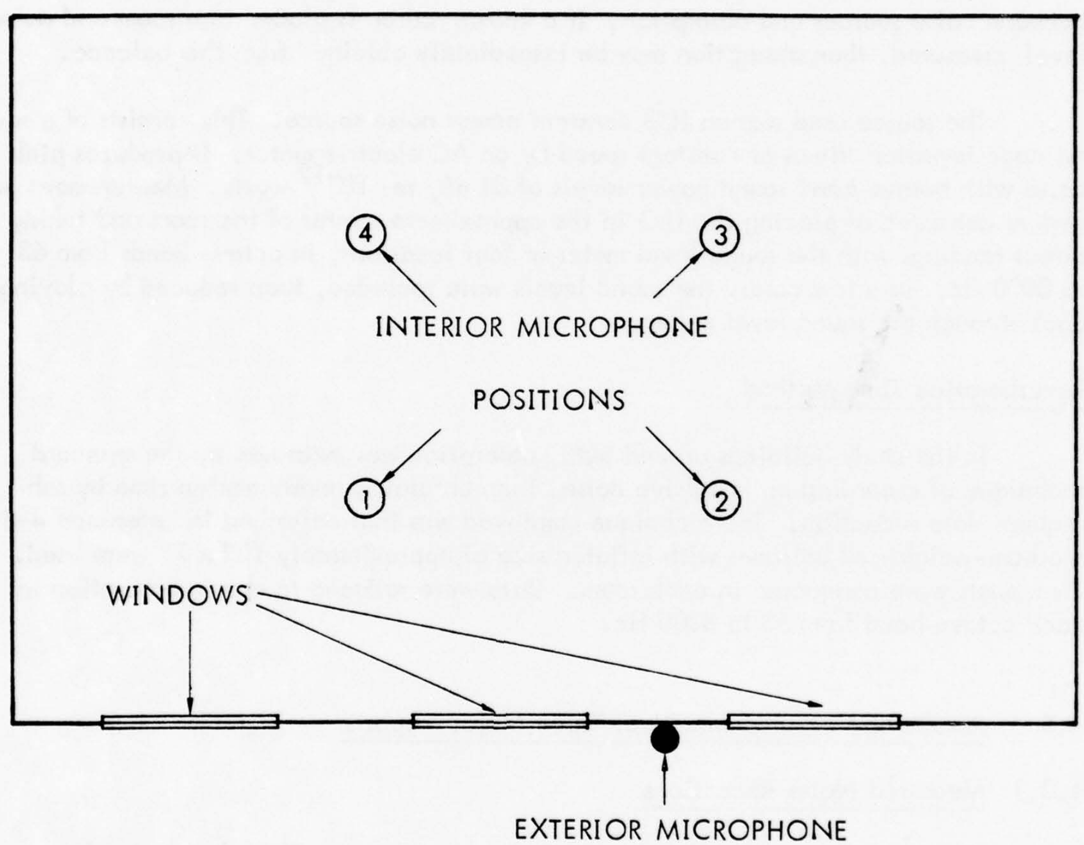

FIGURE 4-1. TYPICAL MICROPHONE ARRANGEMENT FOR NOISE REDUCTION MEASUREMENTS.

4.2.3 Sound Absorption Measurements

Two methods were used to measure interior acoustic absorption. At the study buildings around LAX and DEN, the procedure used was to measure noise levels produced in a room by a standard noise source. For the acoustic absorption measurements at the study building around BOS, the standard reverberation time method[4-3] was used.

Noise Source Method

As discussed in Chapter 3, noise level inside a room is determined by a balance between noise sources and absorption. If a known source is placed in a room and noise level measured, then absorption may be immediately obtained from this balance.

The source used was an ILG constant power noise source. This consists of a squirrel cage impeller driven at constant speed by an AC electric motor. It produces pink noise with octave band sound power levels of 81 dB, re: 10^{-12} watts. Measurement procedure consisted of placing the ILG in the approximate center of the room and taking direct readings with the sound level meter at four locations, in octave bands from 63 to 8000 Hz. In a few cases, the sound levels were recorded, then reduced by playing back through the sound level meter.

Reverberation Time Method

In the study buildings around BOS, absorption was measured by the standard technique of recording an impulsive noise, then obtaining reverberation time by subsequent data reduction. The technique employed was that described in Reference 4-3. Medium-weight red balloons with inflated size of approximately 10" x 7" were used. Two bursts were conducted in each room. Data were reduced to obtain absorption in each octave band from 63 to 8000 Hz.

4.3 Results of Measurements Near Three Major Airports

4.3.1 Measured Noise Reductions

Measured noise reductions are shown in Appendix G. The tabulated values shown for each room are the average over all measurements. The standard deviation for measured noise reduction is shown for each room. Variation in each room is due to a combination of variation of aircraft spectra plus the usual point-to-point noise variation in a room.

A comparison of measured and predicted noise reduction is also presented in Appendix G, together with a statistical analysis of the differences. This analysis shows that the variations obtained in the measurement program are consistent with the computed confidence limits presented in Appendix B for application of EWR to aircraft noise. The use of EWR as the calculation procedure in this project is thus well validated.

4.3.2 Measured Absorption

Table 4-1 shows the absorption coefficients obtained for several combinations of room absorption features. Absorption values for classrooms and hospital rooms shown in Appendix E for LAX, BOS and DEN are the actual measured values, in sabins.

For classrooms, absorption values were on the order of 800 sabins with negligible variation introduced by the presence of students. The minimal variation in total absorption due to students was due to the low (2 sabins per child based on 4.75 sabins for adults[4-4]) acoustic absorption introduced by the presence of each child. For a typical classroom occupancy of 25 children, the additional absorption comes to 50 sabins, amounting to less than 7 percent of the total absorption. Absorption measurements of several classrooms with and without students showed no significant difference, confirming this result.

For hospital rooms, measured absorptions ranged from 125 to 520 sabins depending primarily on room size. A typical value for a one- or two-bed patient room was 150 sabins.

4.3.3 Measured Aircraft Noise Levels

Although validation of the aircraft noise model discussed in Chapter 3 was not an objective of the measurement program, over 500 exterior noise events were recorded in the course of the NR measurements. A comparison of measured levels with predictions from the fleet median noise contours is presented in Appendix G. The predicted levels were slightly conservative, but fell in a reasonable range relative to the spread of measured levels.

4.4 Investigation of Buildings

In order to develop basic data and procedures to determine the feasibility, practicability and cost of soundproofing buildings near airports, field investigations of selected schools and hospitals were made for each construction region as discussed in Section 3.3.1.

Approximately ten (10) buildings were selected within each of the airport noise impacted areas as well as other non-impacted areas.

Field investigation of buildings and noise measurements of rooms most closely affected by aircraft noise were conducted simultaneously at the following sites: Logan International Airport (Boston, Massachusetts), Los Angeles International Airport (Los Angeles, California), and Stapleton International Airport (Denver, Colorado). Building investigations were conducted at the following airport sites: Sky Harbor Airport (Phoenix, Arizona), William B. Hartsfield International Airport (Atlanta, Georgia), and Miami International Airport (Miami, Florida).

TABLE 4-1. SUMMARY OF MEASURED AVERAGE INTERIOR ABSORPTION COEFFICIENTS

Absorptive Materials	Classrooms	Hospital Rooms
None	.17	.23
Acoustic Tile or Carpeting or Drapes	.21	.27
Two of the Above	.30	.40

Roof and ceiling construction were categorized by entries for single joist or attic space construction, roof slab or deck construction, rafter spacing, joist spacing exterior materials, ceiling material, insulation and whether vented or unvented attic space.

Roof construction entries included concrete, wood or metal deck and thicknesses, rafter spacing, and joist spacing (if attic space construction).

Exterior material included entries for wood or composition shingles, built-up roofing and the number of plys, concrete or concrete tiles and other materials.

Four types and thicknesses of ceiling material are listed and a space for other types of ceiling materials.

Insulation type and thicknesses had an entry space.

Attic space was checked as vented or unvented.

Because windows are a main source of noise transmission, the following details were noted on the form: the number of windows per room; the window size; the thickness of glass; whether laminated; the number of plys; whether double glazed; the thickness of air space; whether jalousie; the width of slats and their overlap when closed, if normally opened; the fraction of window opened; operable or nonoperable windows; and a description of the frame type and seal.

Exterior doors were examined only if a substantial number of rooms had exterior doors. These were checked for solid wood, hollow core of wood or steel, and for the type of seal which included the gap at bottom, weather stripping or other types of seal. A check was made if there was a storm door. Sliding glass doors were considered to be windows.

Ventilation systems were checked for windows only, central forced air, or through the wall air conditioning and the number per room and dimensions of the opening.

Room interiors were examined to provide the following information relevant to the interior acoustical characteristics: the percent of floor carpeted, the percent of wall covered with heavy drapes, whether or not there was acoustical tile on the ceiling and how many doors lead to interior rooms and hallways.

Summaries of building investigation results by name of building, location, distance, construction type and material, size and other relevant data are shown in Appendix D.

The building investigation was conducted in this manner: The building authorities were contacted and permission was obtained to inspect the buildings; take sound measurements, where required; take photographs and procure any available pertinent construction drawings. In most cases the area FAA office made these introductory arrangements: School and hospital administrators generally referred the investigators to the facility departments to obtain detailed plans. A worksheet, as shown in Appendix C, was prepared to record relevant architectural and acoustical data and is described as follows:

The average daily occupancy of the buildings was noted. Staff and students and/or patients for schools and hospitals as well as day and nighttime occupancy were recorded.

Building size was recorded by noting the number of stories as well as length and width. Where the particular complex was composed of more than one building or the building was of a complex shape, the longest distance between the extreme ends of the building was noted as the length, and the shortest distance between the extreme ends of the building was noted as the width.

Building size was also described by available site or key plans which facility departments were usually able to supply. The key plans also denoted the usage of various rooms, and the site plans gave the orientation with regard to north and the different elements of the building complex.

Room size was obtained by procuring prints of plans; photocopying pertinent portions of architectural plans; making sketches from non-reproducible plans; or physically observing, measuring, and sketching room plans in the absence of the above alternatives. The room use and occupancy were recorded with the number of rooms in the complex.

Construction materials and details were determined through a careful study of detailed architectural sections, elevations, detailed plans and schedules and were corroborated by physical on-site inspection sketching and photographing.

Wall construction was described by a separate listing of outside and inside materials and thicknesses. Twelve alternative outside walls and thicknesses were listed. A check entry "other" was provided for the outside wall type other than those listed.

Interior finish material of exterior walls was listed by fifteen types and thicknesses with an "other" listing for entry of material not covered by the list.

For other arrangements in exterior walls, five alternative entries were listed to be checked.

Insulation in stud space was listed with an entry for type and thickness.

Special features included entries to be checked for resilient mounting of panels, fiberboard under panels, on one side or both sides, double layer panels, continuously or laminated.

REFERENCES - CHAPTER 4

4-1. Sharp, B. H., Plotkin, K. J., Davy, B. A., and Sutherland, L. C., "A Study of the Effect of Environmental Variables on the Measurement of Noise from Motor Vehicles", Wyle Research Report ECR 74-18.

4-2. McKaig, M. B., "Use of Flush-Mounted Microphones to Acquire Free-Field Data," AIAA Paper 74-92, January 1974.

4-3. Beranek, L. L., Noise and Vibration Control, McGraw-Hill, 1971.

4-4. Berenek, L. L., Music, Acoustics & Architecture, John Wiley & Sons, 1962.

CHAPTER 5

SOUNDPROOFING APPLICATION AND BENEFITS

5.1 Soundproofing Application

5.1.1 Soundproofing Principles

Soundproofing a building consists of eliminating or reducing the transmission of sound into it. The first step is to eliminate leaks which offer no resistance to sound, such as open windows, vents, cracks, etc. Beyond this point, the specific construction of a building is important. Sound is not transmitted directly from outside to inside, but interacts with the building structure to cause interior noise.

When sound strikes the exterior surface of a wall, it causes the wall to vibrate. The vibration of the exterior wall is transmitted through the structure, causing the interior wall to vibrate; this vibration in turn radiates noise into the interior. Noise reduction measures may therefore be considered in terms of reducing the vibration of the wall.

For a single-panel wall, where inside and outside surfaces move as a unit, noise reduction measures consist of reducing the vibrational amplitude response. All else being equal, adding mass to a wall makes it more difficult to move, so that the most common measure for single panels is to add mass. A limp wall, with mass but no stiffness, is desirable because natural resonances can cause high response amplitudes. Increasing the stiffness of a wall very often changes its vibration characteristics in such a way that noise transmission is increased. The practical implication of this is that when mass is added, it must be done in a way to minimize any stiffness increase. Bonding two plies of material together with isolated spots of glue, for example, is preferable to continuous bonding.

The transmission loss (TL) of a single panel is limited to that given by the mass law for limp panels. In practice it is usually less, due to stiffness effects. Large transmission loss for a single panel can be achieved with a thick brick or concrete wall. Comparable transmission loss can be obtained with a much lighter structure, however, by utilizing double-panel wall construction.

Two separate panels, separated by a large air space and vibrationally isolated from each other, will have a TL equal to the sum of the TL of the two panels. This is because the noise incident on the second is that transmitted by the first. In practice, for walls of reasonable thickness, this ideal performance is considerably degraded by the following factors:

- Strong acoustic coupling of the panels due to the air space being small compared to a wavelength.
- Build-up of a reverberant sound field in the air space.
- Direct vibrational "bridging" due to connecting structure (studwork, floor and ceiling connections).

These factors can be reduced by increasing the air space (limited for walls, but quite practical for roofs), introducing absorptive material, and avoiding direct bridging by using staggered studs, resilient mounting, etc.

Where extreme noise reduction is needed — such as in recording studios or acoustic laboratories — elaborate measures such as double walls, vibrationally isolated floors and walls, floating rooms, etc., are used. Within the context of the present program, which must be limited to reasonable methods applicable to public building construction, soundproofing techniques may be considered to consist of eliminating leaks and then applying those methods noted above for single- and double-panel wall construction. This includes both replacing components (such as replacing single glazing with double) and modifying walls according to these principles.

5.1.2 Rehabilitation of Existing Buildings

Soundproofing an existing building consists of identifying which component elements provide transmission paths into the building, then incorporating appropriate modifications. Up to a certain point, modifications can readily be identified from comparative transmission loss, and consist simply of substituting one component for another. For example, if an unsealed hollow-core door is the only transmission path, a 10 dB improvement can be obtained by replacing it with a weatherstripped solid-core door.

Slightly more sophisticated modifications include adding insulation and/or layers of paneling to existing walls. Some very effective soundproofing techniques, such as staggered studs or fiberboard under paneling, are not suitable for retrofit because they would involve virtual demolition of the existing structure and construction of a new wall.

An important concept to keep in mind is that soundproofing is very much a leak-sealing process. The largest "sound leaks" are attended to first, within the context of the particular building. The logarithmic decibel scale tends to obscure the physical consequences of this. A 10 dB improvement in noise reduction means transmitted sound is reduced by a factor of ten. For example, improving a building with NR = 30 involves identifying and eliminating transmission paths one-tenth the size of transmission paths present in another building with NR = 20. It is also important to realize that the noise reduction after modification is often not governed by the modification, but by what is left unmodified.

Following the principles noted above, the noise reduction analysis of the 60 study buildings was extended to include feasible soundproofing modifications. Required modifications for each building were identified from the calculations summarized in Appendix E.

The following modifications were applied as needed:

- Replace existing windows with sealed double glazing with EWR = 40. This can be accomplished with acoustic window designs with STC $\geq$ 40. An alternative is to install a second layer of glass with at least a 2" air space, and absorptive material around the building. Both layers of glass must be at least 3/16" thick and well sealed.

- Upgrading doors and seals. In some cases "acoustic seals", specifically designed for noise insulation, were required. Examples are neoprene seals which are tightly compressed by the door and mechanical drop seals at the bottom. Seals must be installed all around the door. These seals provide an airtight closure much better than ordinary weatherstripping.

- Acoustic baffling of vents. These are custom-designed baffles which provide an absorptive sound trap without restricting air flow. These may be required for ventilated attic spaces and through-the-wall unit ventilators.

- Adding insulation to walls and attic spaces.

- Adding another layer of material, in effect creating a two-panel wall where the original wall is considered to be the first panel. The new gypsumboard or plaster is mounted on studs, furring strips, or a layer of fiberboard. Using fiberboard was found in Reference 5-1 to improve the TL of a frame or block wall by at least 10 dB, and requires less space than studs or furring strips.

- Eliminating windows and filling the space to match the exterior walls.

The last item is not intended as a recommended modification, but rather as a means of achieving noise reduction commensurate with the potential capability of the wall. In practice, very nearly the same noise reduction could be obtained retaining some window area by using smaller windows of special acoustic design.

Appendix H contains rehabilitation worksheets for each of the rooms considered in the study buildings. The worksheets show the existing noise reduction, and the improved noise reduction after applying various combinations of these modifications. The descriptions given on these worksheets form the basis on which costing information presented in Chapter 6 was developed.

The worksheets in Appendix H do not in themselves provide a useful description of typical retrofit on a regional basis. They were developed in the usual manner of treating each building on an individual basis. Comparing improvements denoted as Stage I, for example, would in general be meaningless. As noted in Section 5.1.2, improved noise reduction is governed by what has been left undone.

There are, however, two clearly definable categories of noise reduction which can be meaningfully correlated on a regional basis. These are:

- Category A: Replace existing windows with sealed double glazing, plus all other modifications necessary to achieve NR performance commensurate with the potential of double glazing. (Increased noise reduction on the order of 10 dB)

- Category B: Maximum feasible noise reduction, including elimination of windows. (Increased noise reduction on the order of 20 dB)

Appendix I contains tabulated summaries of noise reduction improvements according to these categories. Shown are existing noise reduction, improvement to noise reduction, and identification of which stage in Appendix H each corresponds to. The buildings are grouped by region, with schools and hospitals kept separately. Average noise reduction improvement and rms variation about the mean are shown for each grouping.

The two rehabilitation categories identified in Appendix I, together with their cost, form the basis of regional and national soundproofing cost figures developed in Chapter 6.

5.1.3 Soundproofing New Construction

All of the buildings visited in this study are existing structures, so that the only soundproofing option is retrofitting. In most cases the buildings predate jet operations, so that at the time of construction no consideration was given to soundproofing. For planning of future construction, however, it is worth considering the cost of including soundproofing initially vs. modifying later. Such cases, may arise, for example, if existing aircraft noise is not intrusive but it is projected that future noise will be.

Building soundproofing measures usually fall into two categories: replacement or modification of components, and basic construction. When components are replaced or modified, the cost difference between new and retrofit is limited to the cost of discarded components and demolition costs. Typical components considered are:

- Windows — use double-glazed acoustical designs instead of single-glazing.
- Doors — use solid-core with proper seals instead of hollow-core.
- Vents — use designs with acoustic baffling.

Although the cost differential associated with these components is relatively easy to define, demolition costs can be highly variable. This is especially true when a new component — such as a baffled vent or a thicker window — is larger than the original component, and does not fit into the space available.

Basic construction consists of the material and configuration of the walls and roof. Some retrofit measures, such as adding insulation, are almost of the same nature as component replacement. Other retrofit measures consist of things which would usually not be done in new construction. For example, when retrofitting an existing wall, material is usually added to the surface, while a new wall is amenable to interior design features such as staggered studs or resilient mounting of panels. Very often in new construction, one arrangement of the same materials at nearly the same cost can give better noise insulation than another arrangement, while retrofitting the poorer arrangement can be costly. For example, if a double-pane window is constructed on-site, placing the panes several inches apart with absorptive material around the periphery is much better than placing the panes $\frac{1}{2}$" apart which is often adequate for thermal insulation.

It is not possible to provide a comprehensive discussion of new sound-insulated construction because of the tremendous variety of approaches possible. As the degree of noise reduction increases, design also becomes more complex. Noise reduction in excess of 50 dB can require either double-wall construction or quite sophisticated single-wall design. However, noise reduction of up to 40-45 dB for typical classrooms is possible with single-wall construction not very different from many conventional buildings. The following points must be considered in designing such a building:

- Masonry Walls. A 9" brick wall provides sufficient attenuation to achieve 45 dB noise reduction in a classroom if all other transmission paths are eliminated. Poured concrete 6"-8" thick has similar performance. Hollow concrete block 8" thick has about 10 dB less noise reduction, however, due to its porosity and lighter weight. Adding a layer of fiberboard and gypsumboard to the interior of a block wall brings its performance up to that of concrete or brick.

  Masonry walls should preferably be brick or concrete. Block walls, if used, need additional material. Retrofitting an existing block wall would entail relocating electric outlets, moldings, etc., in addition to installing the material itself.

- Frame Construction. An uninsulated frame wall with conventional 2 x 4 studs has a noise reduction 10 to 20 dB less than brick or poured concrete. The performance of such a wall can usually be improved by about 10 dB by filling with insulation and adding fiberboard and gypsumboard to the interior finish wall. Severe modifications — such as adding another layer of framing, insulation, and finish wall — are often needed for further improvement. In new construction, performance similar to brick can be obtained by using staggered studs, insulation, and fiberboard under the interior and exterior finish materials. The additional material would be comparable to retrofitting an existing wall and would perform better.

- Roof. Because ceiling area is often three or four times exterior wall area for rooms in large buildings, this can be an important transmission path. The same general considerations given above for walls apply. One important difference for roofs, however, is that there is often significant empty space between roof and ceiling which can be used to advantage. For example, a roof with unvented attic space (at least one or two feet) can perform 10 dB better than a wall using the same materials on 2 x 4 studs. Absorptive material is also particularly effective because of this reverberation space. By ensuring that there is insulation in the attic space and that vents are properly baffled, transmission can be reduced to less than that of a brick wall.

  Concrete slab roofs are also subject to the same considerations. Providing at least a few inches of space between the slab and the finish ceiling (which must be sealed) and including insulation will usually be necessary if noise reduction of 40-45 dB is desired.

Roof constructions to be avoided are single-joist type, where interior and exterior materials are attached to the same rafters. This has the same difficulty as frame construction walls. Exposed-rafter ceilings with any roof material other than thick concrete and with no interior finish ceilings are clearly not suitable for use in soundproof construction.

- Air Conditioning. Because all openings must be sealed, air conditioning (or mechanical ventilation where cooling is not needed) is needed in soundproof construction. Planning ductwork for central ventilation units is much simpler in new construction than when adapting to an existing building. This is a highly variable item for retrofit. It may be impractical to install central ventilation in an existing building, requiring the use of properly vented window units.

A final comment on soundproof construction must be made. The quality standard is much higher than usual. Mortar must be free of pinholes, all joints must be well sealed, special techniques are required for resilient mounting of panels, etc. Such items are more difficult to estimate cost for; but, in general, if there is a range of labor rates, the workmanship needed will usually entail a higher labor cost than average even for nominally conventional operations.

5.2 Soundproofing Benefits

As developed in Chapter 2 when the external noise environment of a building causes the interior noise levels to exceed threshold values, the occupants may experience interference in the performance of noise-sensitive activity. For schools, the most sensitive activity to noise interference is verbal communication. For hospitals and public health facilities, it is the sleep of convalescing patients. The direct benefit of soundproofing for these cases is then the reduction or elimination of interference with such activities. Although it is difficult to translate this direct benefit into dollars, it can be readily examined on a qualitative basis.

For the case of schools, the benefit of soundproofing in improving verbal communications in the classroom is reflected in an improvement of the quality of education and reduction in stress of teachers and students. Improvement in the quality of education comes about through increased communication between teachers and students as well as the educational value of maintaining interruption-free continuity during verbal lessons. Although this benefit could be quantified to some degree by comparing test scores of students exposed to quiet and noisy environments, the value of an improved quality of education is in effect a priceless commodity.

The reduction of stress in the classroom achieved by lower noise levels results from eliminating the need for raised voices and vocal repetition as attempts to maintain communication during noise interruption from outside the building. As with improved educational quality, the reduction of stress is an intangible benefit which affects not only the participants in the classroom but ultimately their families and society at large.

For hospitals and public health facilities the soundproofing benefit of reduced sleep interference is directly realized by the interned patients in the form of a health and quality-of-life benefit. Additional benefit can also be achieved in the potential reduction of medical attendance effected by sleep-disturbed patients.

In addition to the direct benefits to building occupants as described above, the incorporation of building soundproofing has the potential benefit of reducing energy consumption. Savings in energy are derived from reduced building heating and air conditioning needs resulting from soundproofing techniques such as sealed double-pane windows which reduce the heat and air exchange between exterior and interior. This benefit may be partially offset by increased energy use if mechanical ventilation and/or additional electric lights are added to replace lost natural ventilation when windows and cracks are sealed.

CHAPTER 6

COSTS, FEASIBILITY, AND PRACTICABILITY OF SOUNDPROOFING

The first part of this chapter is devoted to costs, including a discussion of the objectives and procedures for developing costing data. The cost prediction methodology is explained. The development of the cost data base is explained. Regional differences are discussed and explained. A detailed costing example is provided which demonstrates the costing procedure in its entirety. The program costs are provided, and the anticipated cost benefits are provided.

The second part of the chapter covers the feasibility and practicability of soundproofing. The limits and constraints of soundproofing are presented and factors relative to practicability are presented.

6.1 Costs

A major objective of the study was the determination of soundproofing costs of schools, hospitals, and public health facilities on a state, regional, and national basis. Costs were calculated for representative buildings, and then projected to determine the state-wide, regional, and national values. All values are in terms of total costs which include both labor and materials. All costs have been corrected for regional and state variations. These corrections are necessary because labor and material costs are different throughout the country. A final correction for the contractors markup, profit, and contingency is then applied.

6.1.1 Cost Prediction Methodology

The cost per "delta" NR's (in dB's) per square foot of floor space or per room average costs applying average square feet per room in each construction region offered the viable estimating method. These costs including cost coefficients (dollar per square foot) are derived from actual costings of sample buildings in each region.

By applying accepted contractor's pricing practice, the 1977 Dodge Manual has been used in deriving unit costs. It breaks each building item into the smallest unit with detailed and up-to-date accurate cost estimates. This manual is known for its completeness and the accuracy of its geographical adjustment indices.

The noise reductions achieved by A and B rehabilitation categories shown in Chapter 5 are found to be meaningfully correlated on a regional basis. The average costs for each region are derived as shown in Appendix M, and projected to the remaining buildings impacted within 30 NEF, within that region.

6.1.2. Cost Data Base

The cost data base includes the costs of all modifications, the regional cost adjustment factors, and the markup costs.

Three basic cost references were used to develop the cost figures:

(1) The 1977 Dodge Construction Systems Costs, New York: McGraw Hill Information Systems Company, 1976.

(2) The 1977 Dodge Manual for Building Construction Pricing and Scheduling, New York; McGraw Hill Information Systems Company, 1976.

(3) Farley, J.H., Chief Editor, Hospital/Healthcare Building Costs, New York: McGraw Hill Information Systems Company, 1976.

These manuals are comprehensive reference tools for measuring the cost requirement of each modification and/or combination of modifications. The cost figures that are provided are based on national cost averages which are continually collected. These costs have been adjusted to represent early 1977 prices.

Base cost data are updated almost daily from information collected at actual job sites throughout the entire country. These data have been developed for application in terms of square feet. Thus, to calculate the cost of a modification, one needs to know the total square footage of the modification to windows, walls, etc.

For example, the current cost for providing a layer of gypsumboard and plywood on inside walls is:

ITEM	$ PER SQUARE FOOT		
	Labor	Material	Total
1" x 2" Furring	.15	.10	.25
1/2" Gypsumboard	.17	.13	.30
Walnut Veneer	.78	1.62	2.40
Sand and Finish	.46	.15	.61
Total per square foot	1.56	2.00	3.56

The reference sources show labor, material, and total costs per square foot of the modification; however, for simplification only the total figure is used.

Regional Cost Adjustment

Labor costs and material vary widely throughout the United States. Regional or locality adjustments are necessary in order to more accurately estimate actual costs.

The basic cost adjustment data is available from the 1977 Dodge Construction Systems Costs and the 1977 Dodge Manual for Building Construction Pricing and Scheduling. These references provide the most up-to-date and accurate regional cost adjustment factors.

The basic cost adjustment data in both references is arranged by city. The 1977 Dodge Construction Systems Costs provides data on 84 cities in the United States and Canada. The 1977 Dodge Manual for Building Construction Pricing and Scheduling provides data for 152 cities in the United States and Canada. They overlap; and when the Canadian cities are deleted, they provide data on 148 United States cities. The publisher, McGraw Hill Information Systems Company, maintains that the cost adjustment data are accurate for each city and for the region around each city.

There are different procedures to group and utilize the basic locality correction data:

a. by cities

b. by states

c. by construction region

By Cities

These data are provided on a city by city basis. Where interest is centered on a specific local site for potential program implementation these data are recommended for use. However, within the scope of this study other procedures were considered more appropriate to the study's objectives.

By States

The basic cost adjustment data grouped by state provides average cost adjustment factors on a state-wide level. Use of such factors offers an overview of state costs. Appendix K lists the corrected factors which could be used on a state-by-state basis.

By Construction Region

These basic cost correction data are grouped by geographical regions of differing construction practices. This procedure was used in developing soundproofing costs.

The cities listed in the above references were sorted into the six regions representing the Geographical Areas of Differing Construction Practices, and into Alaska, Hawaii, and Puerto Rico. The Cost Adjusting Factors for each city within each region were then totaled and averaged to produce regional factors.

Appendix K shows the resultant correction factors for labor costs and material costs for each region, Alaska, Hawaii, and Puerto Rico. These correction factors were applied to base cost data within a Region to adjust labor, material, and overall costs up or down.

These correction factors do not include correction for temporary labor and material shortages and surpluses, discounts, travel, inflation, and unusual costs, which cannot be predicted on a systematic basis; nor do these costs include the final adjustment for the contractor's markup.

6.1.3 Costing Application

This section provides a practical costing example including the methodology for determining basic costs, correcting for regional cost variations, and the development of dollars per delta NR. Costing methodology and application is the same for schools and hospitals, thus only schools are used in the examples.

The example consists of two high schools in two different locations. The schools are typical of school buildings in terms of size, being neither excessively large or small; and in terms of architecture, that is, in containing no unusual or exotic designs and materials. The example utilizes Category B NR's (estimated 20 dB modification).

The first school (School A) is located in construction region E. The second school (School B) is located in construction region A.

School A structure has 42,336 square feet of floor space with 22.5 square foot windows, ten windows per room, 42 rooms, no air conditioning, 12 inch brick walls, and 1/2 inch painted gypsumboard interior walls.

School B structure has 43,500 square feet of floor space with 24 square foot windows, three windows per room, 58 rooms, no air conditioning, 8" concrete walls, and painted masonry interior walls.

The category B (20 dB) modification is to eliminate the windows and to fill the space with comparable exterior and interior wall materials and finishes; and, since the windows will be sealed, a Heating, Ventilating and Air Conditioning system (HVAC) must be provided.

The first step in determing the cost of the modification is the calculation of the total square footage of the modification. This is because the basic cost source[1] provides costs in terms of square feet of modification. School A has 22.5 square foot windows, ten per room, and 42 rooms, so the total square footage of the modification is:

22.5 square feet x 10 windows per room x 42 rooms = 9450 square feet.

School B has 24 square foot windows, three per room, and 58 rooms. The square footage of the modification to school B is:

24 x 3 x 58 = 4176 square feet

[1] 1977 Dodge Construction Systems Cost, New York, McGraw-Hill, 1976.

The first action to be taken is the removal of the windows. This is called demolition and the cost is $.12 per square foot of the modification.[2] The cost for removing the windows in School A is:

9450 square feet x $.12 = $1134.00,

while the demolition cost for School B is:

4176 x $.12 = $501.12

The next step in the modification is the filling of the window space with material like the existing external wall. These costs are also calculated in terms of the number of square feet of modification, but they vary according to the material used. School A is constructed of 12 inch brick interior walls, and this cost is $9.09 per square foot[3]. School B is constructed of 8" concrete walls, and the cost is $5.88[4] per square foot.

All the window space in School A, 9450 square feet, will be filled with 12 inch brick at a cost of:

9450 x $9.09 = $85,910

The window space in School B will be filled with 8" concrete, at a cost of:

4176 x $5.88 = $24,554.88

The next cost item involves the interior wall modification. This cost is also calculated in terms of the square footage of the modification. School A has 1/2 inch painted gypsumboard interior walls, and this material will be applied to the brick. The cost of 1/2 inch gypsumboard painted is $.91[5] per square foot, so the cost of this action is:

9450 x $.91 = $8599.50

School B requires painting of the installed concrete. This cost is $.42 per square foot[6] so the cost of this action is:

4176 x .42 = $1753.92

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[2] Ibid.
[3] Ibid.
[4] Ibid.
[5] Ibid.
[6] Ibid.

Neither building A nor building B is equipped with a HVAC system, therefore both buildings will require HVAC. The cost of HVAC is computed by the square footage of floor space. The square footage of the floor space in building A is 42,336, and the square footage of floor space in building B is 43,500. The cost of HVAC in high schools is \$4.40[7] per square foot of floor space. The HVAC cost for School A is:

$$42{,}336 \times \$4.40 = \$186{,}278.40,$$

while the cost for School B is:

$$43{,}500 \times \$4.40 = \$191{,}400.00$$

The total cost is the sum of all the modifications that must be made to a building. In this example, the total cost is the sum of the demolition cost, exterior wall cost, interior wall cost, and the cost of HVAC. The total cost of the modification to School A is:

$$\$1134.00 + 85{,}900.00 + 8599.50 + 186{,}278.40 = \$281{,}911.90$$

while the cost for School B is:

$$\$501.12 + 24{,}544.88 + 1753.92 + 191{,}400.00 = \$218{,}209.92$$

Because the cost of construction varies throughout the nation, their total costs must be adjusted for regional variations, the cost correction factor for building in construction region E (School A) is .85, and the correction factor for region A (School B) is 1.10.

The actual cost of School A is:

$$\$281{,}911.90 \times .85 = \$239{,}625.12$$

while the cost for School B is:

$$\$218{,}209.92 \times 1.10 = \$240{,}030.91$$

In both schools, the applied modification yields an interior noise reduction of approximately 20 dB (Category B).

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[7] Ibid.

The costs for improving the attenuation of schools A and B can be expressed in different units based on the total dollars. In addition to total dollars, costing can be expressed in dollars per square foot of classroom or dollars per classroom. Using the example, these units would be:

School A

(1) Dollars per square foot = \$239,625.12 ÷ 42,336 = \$5.67/sq.ft.(Classroom)

(2) Dollars per classroom = \$239,625.12 ÷ 42(Rooms) = \$5,720.00/Classroom

School B

(1) Dollars per square foot = \$240,030.91 ÷ 43,500 = \$5.52/sq.ft.(Classroom)

(2) Dollars per classroom = \$240,030.91 ÷ 58(Rooms) = \$4,140/Classroom

6.1.4 Program Costs

The estimated dollar costs of reducing the interior noise levels of schools, hospitals, and public health facilities to within feasible and practical limits, for existing buildings, are identified as Program Costs. These costs were determined through the application of building attenuation practices defined in Chapter 5 as Category A and Category B modifications.

Applying the methodology and procedures used in the example shown under subsection 6.1.3 and the regional factors shown in Appendix K; state, regional, and national soundproofing costs were derived as shown by Tables 6-1 through 6-7.

o Cost Derivation

Costing values were developed separately for each region, through the following process (National cost values are the simple summation of all regional costs).

- Individual cost calculations were completed for each sample site for each category of modifications (A&B) - see Appendix Q.
- Individual costs were then added giving a total dollar cost for all sample sites for each category.
- The total dollars for each category were divided by total number of rooms to be rehabilitated at all sample sites, producing an average cost per category per room within that region.

TABLE 6-1

SUMMARY OF ALL CONSTRUCTION REGION COSTS
(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	$ Cat. A	$ Cat. B	Number	No. of Student	Number	No. of Patient	$ Cat. A	$ Cat. B	Number	No. of Patient
< 40											11	4441
40-44	20	17189			325	232569	--	--			44	13241
45-49	37	26734			421	285198	2	754	298650		17	6589
50-54	90	69150	11047170		203	123244	10	3046	4631640		12	5289
55-59	150	109440	17787220		76	47420	18	6522	--	8799600	2	820
60-64	215	146230		26969255	32	18939	25	7360		11395430	3	426
65-69	234	149024		27488155			17	6589		10659200		
70-74	203	123244		22833820			12	5289		7588256		
75-79	76	47420		8585990			2	820		1218070		
80-85	32	18939		3530205			3	426		621390		
TOTAL	1057	707370	28834390	89407425	1057	707370	89	30806	4930290	40281940	89	30806

*Limited by feasibility and practicability
**Include public health facilities

SUMMARY	SCHOOL	HOSPITAL
Category A (11 NR ± 2) Cost Coefficient	$4.90/Sq.Ft.	(11 NR ± 1) $12.80/Sq.Ft.
Category B (20 NR ± 3) Cost Coefficient	$5.49/Sq.Ft.	(18 NR ± 2) $11.61/Sq.Ft.

TABLE 6-2

SUMMARY OF CONSTRUCTION REGION COST A

(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	$ Cat. A	$ Cat. B	Number	No. of Student	Number	No. of Patient	$ Cat. A	$ Cat. B	Number	No. of Patient
<40											1	92
40-44	2	2365			39	24795					5	1159
45-49	3	1010			43	29536	1	92	226000		3	1254
50-54	9	6172	1108090		44	32381	1	370	727020		2	978
55-59	14	9451	1711680		11	6339	2	200		405600		
60-64	28	16258		3385200	6	4328	2	589		1196520		
65-69	26	19075		3967600			3	1254		2541640		
70-74	44	32381		6739200			2	978		1994200		
75-79	11	6339		1320800			0	--				
80-85	6	4328		904800			0	--				
TOTAL	143	97379	2819770	16317600	143	97379	11	3483	953020	6137960	11	3483

*Limited by feasibility and practicability

**Include public health facilities

SUMMARY	SCHOOL	HOSPITAL
Category A (10 NR $\pm$ 3)		(11 NR $\pm$1)
Cost Coefficient.................	$5.11/Sq.Ft.	$15.14/Sq.Ft.
Category B (18 NR $\pm$4)		(17 NR $\pm$2)
Cost Coefficient.................	$5.90/Sq.Ft.	$15.62/Sq.Ft.

TABLE 6-3

SUMMARY OF CONSTRUCTION REGION COST B
(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	$ Cat. A	$ Cat. B	Number	No. of Student	Number	No. of Patient	$ Cat. A	$ Cat. B	Number	No. of Patient
<40											1	662
40-44					6	4924			--		-	-
45-49					7	4687	1	662	72650		1	60
50-54	1	1864	187250		10	5104	--	--	--		2	1050
55-59	1	1260	119840		2	2353	--	--	--			
60-64	5	3060		358,545	1	553	--	--		--		
65-69	6	3427		399355			1	60		28160		
70-74	10	5104		597580			2	1050		492730		
75-79	2	2353		276930			--	--				
80-85	1	553		67045			--	--				
TOTAL	26	17621	307090	1699455	26	17621	4	1772	72650	520890	4	1772

*Limited by feasibility and practicability
**Include public health facilities

SUMMARY	SCHOOL	HOSPITAL
Category A (11 NR $\pm$ 2)		(11 NR $\pm$ 1)
Cost Coefficient	$3.03/Sq.Ft.	$1.14 / Sq. Ft.
Category B (20 NR $\pm$ 1)		(23 NR $\pm$ 1)
Cost Coefficient	$3.54/Sq.Ft.	$ 4.89/Sq.Ft.

TABLE 6-4

SUMMARY OF CONSTRUCTION REGION COST C
(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	$ Cat. A	$ Cat. B	Number	No. of Student	Number	No. of Patient	$ Cat. A	$ Cat. B	Number	No. of Patient
<40											4	1721
40-44	-	-			36	27729					4	1035
45-49	5	3674			35	24645					1	774
50-54	11	9430	1315210		10	6649	1	52	89490		1	477
55-59	10	7900	1080110		9	6825	4	1721		2969060		
60-64	25	18299		3452840	7	4170	3	983		1697170		
65-69	20	13071		2466990			1	774		1335030		
70-74	10	6649		1278380			1	477		834330		
75-79	9	6825		1287740			--	--		--		
80-85	7	4170		787740			--	--		--		
TOTAL	97	70018	2395320	9273690	97	70018	10	4007	89490	6835590	10	4007

*Limited by feasibility and practicability
**Include public health facilities

SUMMARY	SCHOOL	HOSPITAL
Category A	(13 NR $\pm$ 4)	(11 NR $\pm$1)
Cost Coefficient	\$3.86/Sq.Ft.	\$11.26/Sq.Ft.
Category B	(22 NR $\pm$5)	(18 NR $\pm$1)
Cost Coefficient	\$5.35/Sq.Ft.	\$11.23/Sq.Ft.

TABLE 6-5

SUMMARY OF CONSTRUCTION REGION COST D
(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	$ Cat. A	$ Cat. B	Number	No. of Student	Number	No. of Patient	$ Cat. A	$ Cat. B	Number	No. of Patient
<40											5	1966
40-44	11	9480			143	118351	--	--			18	4505
45-49	18	15756	--		206	150886	--	--			8	2170
50-54	46	39912	6364050		63	37724	5	1518	2691520		3	622
55-59	87	68743	10958750		24	14388	5	1966		3448570	1	626
60-64	86	68959		12983040	5	3664	13	2987		5246320	1	186
65-69	101	66387		12489120			8	2170		3809050		
70-74	63	37724		7103040			3	622		1097250		
75-79	24	14388		2728320			1	626		1037080		
80-85	5	3664		682040			1	186		324740		
TOTAL	441	325013	17322800	35985560	441	325013	36	10075	2691520	14963010	36	10075

*Limited by feasibility and practicability
**Include public health facilities

SUMMARY

	SCHOOL	HOSPITAL
Category A	(10 NR $\pm$2)	(11 NR $\pm$1)
Cost Coefficient	$4.79/Sq.Ft.	$13.30/Sq.Ft.
Category B	(20 NR $\pm$4)	(19 NR $\pm$3)
Cost Coefficient	$5.65/Sq.Ft.	$13.18/Sq.Ft.

TABLE 6-6

SUMMARY OF CONSTRUCTION REGION COST E

(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	$ Cat. A	$ Cat. B	Number	No. of Student	Number	No. of Patient	$ Cat. A	$ Cat. B	Number	No. of Patient
<40												
40-44	3	3112			48	29775	--	--			1	626
45-49	4	2875			48	29581	--	--			2	1277
50-54	8	4213	694530		37	21690	--	--			2	1252
55-59	11	6933	1156200		20	11825	--	--				
60-64	37	22450		3697070	4	2295	1	626		1144920	1	130
65-69	33	19773		3256550			2	1277		1865830		
70-74	37	21690		3573560			2	1252		2287400		
75-79	20	11825		1947340			--	--				
80-85	4	2295		382860			1	130		189990		
TOTAL	157	95166	1850730	12857380	157	95166	6	3285		5488140	6	3285

*Limited by feasibility and practicability

**Include public health facilities

SUMMARY

	SCHOOL	HOSPITAL
Category A (11 NR ±1) Cost Coefficient	$5.24/Sq.Ft.	No Sample
Category B (19 NR ±2) Cost Coefficient	$5.19/Sq.Ft.	

TABLE 6-7

SUMMARY OF CONSTRUCTION REGION COST F
(NO MARKUP INCLUDED)

Interior Levels (dB)	SCHOOL						HOSPITAL**					
	EXISTING		REHABILITATION*		AFTER		EXISTING		REHABILITATION		AFTER	
	Number	No. of Student	Cat. A	Cat. B	Number	No. of Student	Number	No. of Patient	Cat. A	Cat. B	Number	No. of Patient
< 40											--	--
40-44	4	2232			53	26995	--	--			16	5916
45-49	7	3419			82	45863	--	--			2	1054
50-54	15	7559	1378040		39	19696	3	1106	1123610		2	910
55-59	27	15153	2760640		10	5690	7	2635		1976370	1	194
60-64	34	17204		3092560	9	3929	6	2175		2110500	1	110
65-69	48	27291		4908540			2	1054		1079490		
70-74	39	19696		3542060			2	910		882340		
75-79	10	5690		1024860			1	194		180990		
80-85	9	3929		705720			1	110		106660		
TOTAL	193	102173	4138680	13273740	193	102173	22	8184	1123610	6336350	22	8184

*Limited by feasibility and practicability
**Include public health facilities

SUMMARY	SCHOOL	HOSPITAL
Category A (10 NR ±2)		(12 NR)
Cost Coefficient	$6.18/Sq.Ft.	$12.84/ Sq. Ft.
Category B (18 NR ±2)		(15 NR ±4)
Cost Coefficient...............	$6.11/Sq.Ft.	$13.13/Sq.Ft.

- The regional dollar/category/room unit was then applied to all the rooms of all buildings to get a total regional cost. Units were developed for schools and hospitals.

The following shows National Total Costs.

	Number	Costs
Schools	1057	$118,241,815
Hospitals and Public Health Facilities	89	45,212,230
Subtotal	--	$163,454,045
25% Mark-up		40,863,511
TOTAL	1146	$204,317,556
		≈ ($204,300,000)

These figures are based on early 1977 prices, and do not include conditions such as union rules, weather, or other cost escalations. For example, in a locality where many building projects are underway, prices and contractor fees will be somewhat higher. In localities where few building projects are underway, prices are likely to be somewhat lower. These effects are very local and are not predictable.

The distribution of cost on a state-by-state basis is provided in Appendix N.

6.1.5 Cost Benefits

Although the soundproofing benefits are mentioned in qualitative terms in Chapter 5, the following summarizes some of the obvious indirect benefits with plausible cost effectiveness calculations:

(1) More Effective Communication - Soundproofing permits more effective face-to-face, teacher-to-class, doctor-to-nurse, telephone, radio, etc., communication.

(2) Less Aggravation - Aircraft noise in schoolrooms results in aggravated teachers. A decrease in the noise results in less aggravation; thus, making the teacher's job more pleasant and desirable. This is also related to turnovers since contented teachers are less likely to resign. This results in a decrease in personnel costs, school operating costs, and less tax to local citizens.

(3) Fewer Complaints/Litigations - Less noise means fewer angry people. This means less actions against airports, airlines, airport sponsors, and federal agencies.

(4) Greater Positive Feeling Towards Aviation - People who are greatly disturbed by aircraft noises are not likely to look favorably on aviation. They are not likely to support aviation, aviation research and grants, and improved aviation technology.

(5) Greater Positive Feeling Towards Airlines - People who are greatly disturbed by aircraft noises do not look favorably upon airline companies. Reducing the noise may reduce their disfavor. This may have some impact on their likelihood of using aviation as a means of travel. Since aviation is the safest way to go, this means an impact on public safety.

(6) Improved Land Utilization - Effective soundproofing means that land very near airports can be more effectively used. Certain kinds of buildings may be desirable there such as prisons, some hospitals, etc.

(7) Greater Airport Flexibility - Proper and effective soundproofing (retrofitting) may allow airports to be built closer to built up areas.

(8) Less Sleep Disturbance - A reduction of aircraft noise through soundproofing will result in less sleep disturbance both in terms of waking up and being able to fall asleep.

(9) Cleaner Air - Proper soundproofing requires the utilization of effective HVAC technology. This results in better air quality within buildings and can result in a more comfortable environment. Air-conditioned schools are more comfortable and conducive to learning than are non-airconditioned schools.

(10) Fewer Respiratory Problems - Soundproofed schools with good HVAC will be most pleasant to children and teachers who are troubled by a variety of allergies and other respiratory disorders. The same is true for hospitals.

(11) Less Distraction - Soundproofed (i.e., sealed buildings) permit less outside distraction. School children are less likely to be looking outside at some disturbance and more likely to pay attention to the teacher.

(12) Greater Energy Conservation - Soundproofing uses similar technology to insulation, thus, there is a major savings in terms of heat and cooling loss.

(13) Improved Fire Safety - Greater use of heavy wall construction slows down and lowers the danger from fire.

(14) Improved Building Construction - Effective soundproofing requires careful attention to detail during the construction and retrofitting of a building. This means a heavy supervisory and inspection function, however, short cuts and sloppy workmanship will be avoided, thus resulting in a better built building.

(15) Greater Desirability of Property - An effectively soundproofed building within a high noise area is simply more desirable than an unsoundproofed building. This improves sale and resale value.

(16) Increased Property Value - Although many buildings around airports do not lose value because of noise, an effectively soundproofed building can command a high sales price or rental. Both of these factors may impact the finances of the local community.

Classroom Disturbance Cost Savings

The passage of an airplane over a highly impacted school results in a disruption of ongoing classroom activity. The teacher must momentarily stop teaching, and the students can do nothing constructive for the duration of the disturbance. As soon as the aircraft has passed, the classroom activity can resume.

Although each disturbance is only momentary, it is a disturbance; and because productive activity stops, it is wasted time.

In an effort to quantify the cost of waste time, certain assumptions and concepts must be considered.

1. The operation of a school is a continual cost. Teachers are paid throughout the day for productive time and for waste time.

2. Original building costs and operating costs can be amortized over time and distributed on a per-student basis.

3. Waste time can be viewed as an unnecessary cost to the taxpayer even though the removal of the disturbance does not affect the actual salaries of teachers or per-student costs.

4. The cost of soundproofing is a dollar value, and the cost of waste time is a dollar value. If the cost of soundproofing is greater than the cost of the waste time, soundproofing is not cost effective because there is no return. If the cost of soundproofing is less than the dollar value of the waste time, soundproofing is cost effective because there is a return in productive time. There is, in effect, a net gain in productive time, and thus, a gain in value.

Classroom Disturbance Cost can be quantified as follows:

$$\text{Cost} = \frac{t \times \overline{S_h} \times \overline{N_t} \times L}{60}$$

where:

t = total teaching time lost in minutes

$\overline{S_h}$ = average teacher's salary in dollars

$\overline{N_t}$ = average number of teachers employed

L = life cycle, in days, = 180 days x 10 years

Revised Formula

Benefit in dollars = $[\, t \times \overline{S_h} \times \overline{N_t} \times L \,] - [\, C_{sp} \,]$

where C_{sp} = Cost of soundproofing

Classroom Disturbance Teacher Cost - Example

Assume:

t = 10 minutes (total disturbance per day)

$\overline{S_h}$ = \$10.66 per hour (based on the national average)[8]

$\overline{N_t}$ = 100 teachers

then

$$\text{Cost} = \left(\frac{10.66}{60}\right) (100)\ (1800)\ (10)$$

Value of the lost time = \$320,000.

- If the cost of the modification is less than \$320,000, there is a net gain.

- If the cost of the modification is greater than \$320,000, the soundproofing has cost more than the value of the teaching time that was saved.

[8] U. S. Bureau of the Census, Statistical Abstract of the United States, Washington, D. C., Department of Commerce, 1975, p. 130.

This analysis is based on the distraction time occuring in 1,057 schools. Distraction time is considered to be a minimal 20 seconds per interruption due to an aircraft flyover. The distraction time per school was calculated on the basis of the number of flights made during the school day. Thus, a school, impacted by flights from Portland International Airport, would have approximately 30 flyovers per school day. Thirty flyovers at 20 seconds each is a total daily disruption time of 600 seconds, or .16 hour.

Since there is only one school, the total lost time is 1 x .16 hour, which is .16. Multiplying this by the number of teachers (30) gives the total manhours of teachers' time lost. The total hours lost per day in this school is 4.8 hours. The average teacher's salary is $10.66 per classroom hour, so the value of the lost time is $10.66 x 4.8 hours, which is $51.17 per day. This is the value of the lost teaching time every day due to aircraft noise.

$51.17 translates to a yearly cost of $51.17 x 180 days which is $9,210.60. This is the cost of the lost teacher time every year in this particular school.

Costs and benefits are not generally calculated on the basis of one year of operation. Similarly, a multiple of 10 years (without escalation) as the average time has been used. This figure was used as a general guideline in that this is a reasonable time frame for a modification to a structure. $9,210.60 x 10 years equals a benefit of $92,106.00.

If the cost of soundproofing is less than $92,106.00, the cost of soundproofing will be offset by the recovery of productive teachers' time in less than ten years. If the cost is greater than $92,106.00, a break even point will not be reached until some time after 10 years.

In the case of this particular school, the actual projected cost of the modification is $28,068.00 which is considerably less than $92,106.00.

The following summarizes this benefit calculated for all 1,057 impacted schools nationwide. The total benefit is the value of the teachers' time saved.

- <u>Teachers' Time Lost Due to Aircraft Noise</u> (Nationwide)

  One Aircraft Operation for Nation's Impacted Teacher: $\frac{(707,370 - 43,923)}{25} = 26538$

  $$\$10.66 \times \frac{1}{180} \text{(hour)} \times 26,538 = \$1,572$$

  Average Daily Jet Operation at Jet Operated Airports (School Periods) - 10

  Average Value Per Day - $15,720

  Construction Costs to Remedy Schools $118,200,000
  (Without Markups)

Student Time cost can be quantified as follows:

In a similar order of magnitude calculation, one can derive a student cost of predominantly public elementary and secondary education as $1,369.63 (1974/1975) as given in the Digest of Education Statistics in 1976.

Average Annual Education Cost Per Student	$1,369.63	1974/1975
Estimated Annual Cost Per Student	1,570.00	1976/1977
Average Class Hour Cost Per Student (Average 7 Class Hours - 180 Days)	1.45	1976/1977

o Student's Time Lost Due to Aircraft Noise

One Aircraft Operation for Nation's Impacted Students (707,370 - 43,923) = 663,447

$$\$1.45 \times \frac{1}{180} \text{ (hour)} \times 663,449 = \$5,344$$

Average Daily Jet Operation Estimates (School Period) at Jet Operated Airports	10
Average Value Per Day	53,440
Construction Costs to Remedy Schools (Without Markups)	118,200,000

o Hospital Disturbance Cost

Since an average cost for an inpatient is given as $118.54 per day in the Hospital Statistics in 1975, one can estimate the similar order of magnitude following a recent thesis[9] in which patient stay was found to be correlated with noise.

$135 (1977 Cost) x 30,806 (impacted patients) = $4,158,810 per one day delay in discharge rate.

In this connection, the other study entitled: "Noise in Hospitals Located Near Freeways" is noteworthy in that the recurring highway noises did not disturb patients or staff until the noise level reached 72 PNdb.[10] Regardless of traffic noise

[9] Daniel Fife and E. Rappaport, "Noise and Hospital Stay," Public Health Brief, American Journal of Public Health, July 1976, Vol. 66, No. 7.

[10] R. M. Towne and et al, Noise in Hospitals Located Near Freeways, Towne and Associates, Inc., Seattle, Washington, January 1964.

content, the total noise environment had little bearing on the recovery rate of patients, and virtually no bearing on a doctor's decision as to where he will hospitalize his patients. Thus, although there is still a question as to the impact of aircraft noise on hospital stay, such a benefit is quantifyable.

Energy Conservation Benefit and Quantification

The soundproofing of buildings has two direct effects - (a) increased energy consumption by air conditioning equipment due to the elimination of natural ventilation and (b) reduction in heat loss due to the sealing of walls, windows, and other openings. A related study[11] found that energy savings realized by reduction of heat loss outstrip the increased energy consumption of air conditioning.

Another side effect is reduced humidity during winter months causing some discomfort with no appreciable health hazards. Also, the increased indoor air pollution such as increased exposure to cigarette smoke particles and odors may require separate areas for smokers and non-smokers.

The energy consumption can be calculated as follows:[12]

- Net Energy Saving = (Energy Savings by Sealing and Modification) - (Added Ventilation Energy)
- Energy Saving by Sealing = (Infiltration Constant) (C)) x (Building Volume) x 365 x 24
- Energy Saving by Modification = (Thermal Transmittance (U) Factor) x (Area) x (Local Annual Degree/Day x 24)
- Added Ventilation Energy (kwh/year) $= \frac{\text{Building Volume}}{233}$
- Weighted average energy cost for gas, oil, and electricity is applied to the above energy consumption to translate into dollar costs.

Table 6-8 shows the results of net energy saving calculations attributed by the soundproofing programs.

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[11] Federal Energy Administration, "Energy Conservation in New Building Design," Conservation Paper No. 43 B, August, 1975.

[12] Wyle Laboratories, "Insulation of Buildings Against Highway Noise," August, 1976.

TABLE 6-8

SUMMARY OF NET ENERGY SAVING DUE TO BUILDING INSULATION

Construction Region	Impacted Airport No.	School Net Savings	School No.	Hospital Net Savings	Hospital No.	Public Health Facility Net Savings	Public Health Facility No.	TOTAL
A	39	$ 226,957	143	$ 21,226	11		-	$ 248,182
B	13	19,692	26	1,903	3	$ 533	1	22,110
C	78	17,472	97	2,966	8	95	2	20,534
D	171	2,431,702	441	53,111	33	14,402	3	2,499,215
E	148	267,867	157	8,712	5	727	1	277,307
F	259	649,777	193	139,080	17	11,514	5	800,371
NATIONAL TOTAL PER YEAR	708	$ 3,613,467	1,057	$ 226,998	77	$ 27,261	12	$ 3,867,727
10-YEAR CYCLE COSTS (without escalation)		$ 36,134,676		$2,269,982		$ 272,610		$38,677,268

NOTE:

Region	Yearly-Deg.-Days	Temp. Diff.	C(Infiltration Constant)
A	1799		
B	1765	25	.57
C	214	50	1.13
D	5634	75	1.6
E	2983		
F	6283		

U Factor

Single Pane Glass - 1.13
Double Pane Window .58

1977 Weighted Ave. Energy Cost

Region	Gas ($/mcf)	Oil($.gal)	El. (c/kwh)
Northeast	1.64	.446	5.38
North Central	1.03	.415	3.05
South	.89	.426	2.95
West	.94	.446*	2.56

*Federal Energy Administration, January, 1977.

Heating Value Efficiency: Coal - 7800 BTU/lb.
Oil - 98000 BTU/gal.
Gas - 820 BTU/c.f.

6.2 Feasibility and Practicability

6.2.1 Feasibility

Feasibility for the purposes of this study is defined as the potential for modification. A modification may be feasible if:

1. the actual work to be performed is within the state-of-the-art of building work. Modifying windows, applying layers of gypsumboard, etc., are within the state-of-the-art.

2. the cost of the modification is not excessive, in terms of reasonable and normal costs. If a particular piece of work requires unusual material or skill, and thus the costs are out of line, the modification is not considered feasible. Similarly, modification to a building with a life expectancy of less than ten years would require a careful trade off analysis from a cost standpoint.

6.2.2 Practicability

Technical limitation refers to the net result of engineering and architectural rehabilitation. In the context of this study, soundproofing rehabilitation was found to be practical in that the rehabilitation can be applied to most buildings. Scheduling is required, however, because some rooms cannot be utilized during the rehabilitation work. Since the rehabilitation can proceed room by room, a small number of classes or patients will be disturbed at any one time. Rehabilitation to external doors and the roof will not disturb the occupants.

6.3 Evaluation of Eligibility and Priority for Soundproofing Candidates

The findings of this study may be incorporated in a federal program to fund soundproofing of public buildings. This section of the report provides an evaluation of the elements of such a program related to determining the eligibility of requestors for such funds and a priority system by which applications could be considered. Since many of the underlying questions concerning eligibility and priority for soundproofing funds are based on similar considerations, the two topics are treated together. Discussed below are recommendations and key factors to be considered.

6.3.1 Eligibility and Priority

Applicable Use Category

The first step in determining the eligibility of a specific application for funds should be to verify that the actual or planned usage of the building falls within the usage categories intended by Congress for consideration. Building-use categories specifically covered by this study are schools, hospitals and public health facilities. Additionally,

only rooms directly related to building use (such as classrooms in schools) are specified. Potential areas for clarification include further definition of eligible rooms, further definition of what constitutes a public health facility, the possibility of including other building-use categories and the inclusion of privately owned facilities falling within the above categories. Since the degree of noise impact will vary considerably for buildings within each category, it does not appear feasible to base a priority system for funding on a consideration of use category.

Magnitude of Noise Impact

From both an eligibility and priority standpoint it is important to focus on those buildings most severely impacted by aircraft noise. In regard to eligibility, it is necessary to define the minimum level of impact which qualifies a candidate for soundproofing funds. The manner in which this noise impact is defined can then be used to establish the priority by which qualified applications are considered. The determination of the degree of noise impact from aircraft operations encompasses consideration of the following factors:

1. The most direct indication of the magnitude of noise impact within a building is the amplitude of the aircraft noise levels. The noise levels above which interference with noise-sensitive activities occur are identified in Chapter 2. In addition to the maximum aircraft noise levels which occur, consideration must be given to the duration and number of occurrences of the aircraft noise intrusions. Two approaches to including duration and number are establishing noise criteria in terms of the percentages of time threshold noise levels are exceeded, and the use of an energy-cumulative metric such as NEF or L_{dn}.

2. Another important measure of the degree of impact is the number of people affected. For maximum benefit, buildings with a high level of occupancy may be given preference to buildings with low occupancy.

3. A final consideration in the assessment of noise impact is the building interior noise level in the absence of aircraft noise sources. In order to be considered a source of adverse impact, noise contributions from aircraft would be expected to significantly exceed the noise environment produced by other sources. Non-aircraft noise sources to be considered include internally generated noise such as ventilation equipment, normal conversation, feet shuffling, etc., as well as exterior sources such as highway traffic.

Effectiveness of Soundproofing

Establishing the feasibility of soundproofing to alleviate noise impact as opposed to relocation of facilities or modifications to aircraft operational procedures should be incorporated into the criteria for eligibility. Factors involved in establishing the feasibility include:

1. It should be established that soundproofing would provide a beneficial reduction in level. The desired degree of soundproofing must be consistent with degrees identified in this study as being feasible. Furthermore, the costs associated with soundproofing should be balanced by the degree of benefit achieved.

2. Since soundproofing has benefit only in reducing building interior noise levels, its feasibility needs to be considered in relation to the extent of noise-impacted outdoor activities.

6.3.2 Technical Evaluation

Once a program is initiated, applications for soundproofing funding will be expected. In part, these applications will be reviewed on the basis of criteria developed from the considerations given above. A substantial part of an application must contain technical documentation of the present noise environment. This will consist of essentially three factors:

- Exterior noise environment, including aircraft and non-aircraft noise sources.
- Present building noise reduction.
- Proposed soundproofing modifications, including cost estimate.

The data to substantiate these factors should be developed by technically trained personnel and presented in a form consistent with FAA eligibility review procedures.

6.3.3 Priority of Programs

Modifications can be funded in four ways:

1. In the order of seriousness of impact
2. by geographical area
3. by random selection
4. all buildings at once

Modifications can be made according to a program based on the severity of impact. In other words, the most severely impacted buildings should be done first; less severely impacted buildings would be done at a later date. Essentially, buildings would be modified in the order of the level of aircraft noise impact, regardless of the geographical area.

A second procedure would be to perform the modifications by geographical area, regardless of the level of the noise impact. This procedure has the advantage of more efficient program control. All work is being performed in a geographical region. All impacted schools are modified at the same time, thus, avoiding confusion as to why one school is being modified but another less seriously impacted school in the same area is not.

A third alternative procedure would be to modify buildings at random. This procedure has the sole advantage of avoiding any dispute about the order of modification. It is possible that many localities and school systems would desire to have their buildings modified first. This procedure avoids lengthy discussions with local officials.

A fourth alternative would be to implement all modifications at the same time. This procedure is probably the most desirable in that no one has to wait for t heir modification. Modifications are made in the shortest time frame, thus allowing the benefits of soundproofing to begin as soon as possible.

The following suggested criteria could govern the funding of the program.

(1) Meeting the eligibility criteria. Before any consideration of funding, a particular building must meet the criteria for eligibility.

(2) Alternate Sources of Funding. If there are other sources of funding available, coordination in program funding should be completed.

(3) Alternate Sources of Noise. If there are other than aircraft sources of noise impact, a proportional funding may be in order.

The criteria implementing the soundproofing program should be based on benefits which the program would achieve. Those anticipated benefits, direct or indirect, discussed, should be weighed against adverse effects and the costs of implementation as well as alternative consequences.

In soundproofing of public buildings near airports, there are substantial benefits--savings of time lost by teachers and students during aircraft noise intrusion and sizeable net energy savings as discussed. Probable local economic and environmental impacts coupled with resource allocation need to be assessed in each case.

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CHAPTER 7

NATIONWIDE NOISE IMPACT

Aircraft noise affects people by disturbing their normal classroom activities, sleep, and health services. Thus, the nationwide aircraft noise impacts are:

(1) To identify the estimated number of schools, hospitals, and public health facilities which are located within the noise sensitive areas around airports and therefore subject to the effects of aircraft noise.

(2) To identify the estimated number of occupants (students and patients) at those public buildings located within the noise sensitive areas near airports.

7.1 Criteria and Methodology

7.1.1 Impacted Area Around Airports

The noise exposure forecast (NEF) takes into account not only the annoyance due to the individual noise event, but the contribution from multiple noise events. Thus, NEF provides a meaningful criterion in terms of impact on people--the effects of noise on classroom speech communication and sleep. The NEF 30 delineates the cumulative noise exposure which is generally regarded as the exposure above which considerable annoyance occurs.

All available NEF noise contours were compiled from FAA Regional Offices, Wyle Laboratories, who participated in the 1974 DOT study of 23 major U. S. airports, and airport authorities/agencies who developed NEF contours. In the event of non-existent or nonavailability of NEF contours, estimates of NEF contours were made by following the procedure developed by the U. S. Department of Housing and Urban Development (Noise Assessment Guidelines, Circular 13902). Then, schools, hospitals, and public health facilities within NEF 30 contours were identified from U. S. Geological Survey maps.

7.1.2 Analytical Process

The first step was to compile data by location of all public buildings located within 30 NEF around those airports which support jet operations. This data base included building types, construction materials, occupancy, classroom or patient room size and number, and other publicly available statistical information.

These data were compiled for all large and medium hub airports across the country. Six large hub airports were analyzed by site visits, each representing six contiguous construction regions in the nation. For small airports, statistical sampling methods were used. Appendix Q shows a complete listing of all sample airports (large / medium hub, and smaller airports including general aviation) utilized for the data base.

Projection Methods for Small Airports

The sampling of small airports is concerned with random variables of public buildings whose means and distributions are not known precisely. The sampling distribution is inferred from observed data which are the results of field investigations conducted in the six construction regions. A random sample size of approximately 40 small airports was drawn in such a way as to insure that each group of small airports had the same chance of being included in the nationwide jet operated small airport population of approximately 639.

The nationwide jet operated small airports are assigned to alternative stratum classifications: initially by population density of the associated area of small airports. Since population density data were not feasible to assemble or to generate, the other two alternatives--population group of city associated with airport and average daily jet operational group of FAA National System of Airport Classification System (1972 National Airport System Plan)--were used.

The following shows a summary of findings:

Stratum Group	Population Group of Associated City	Small Airports	Average Daily Aircraft Operation	Small Airports
A	Above 200,000	20	o Primary System (TP2)* Above 700	16
B	80,000-199,999	6	o Secondary System (SI) 700 -280	126
C	40,000-79,999	60	o Secondary (S) 279-140	170
D/E	Below 39,999	553	o Feeder System (F) Below 139	327
		639		639

Stratum	No. of Stratum	No. of Sample Airports
.	N_1	n_1
.	.	.
.	.	.
$\frac{K}{4}$	N_K	n_k
	N	n

$$\frac{n_1}{N_1} = \frac{n_2}{N_2} = \ldots \frac{n_k}{N_K}$$

*FAA National Airport System Plan, 1972

The above shows that all small airports are subdivided into K stratum of size $N_1, N_2 \ldots N_K$ with $N_n = N$ and simple random sample of size $n_1, n_2 \ldots n_k$ with $n_n = n$.

Let u = true mean of national small airport and u_h be the true mean of the hth stratum, and let $\overline{X}_h$ be the observed mean of the sample n_h drawn from the hth stratum:

Then the unbiased estimate of $u = \frac{1}{N} \sum_{h=1}^{K} N_n \overline{X}_h$

Thus, the estimate of population mean is the weighted mean of the observed subsample mean, where weight applied to the subsample mean $\overline{X}_h$ is N_h / N.

The sample size drawn proportionally and stratified sample is expressed as:

$$\frac{N_h}{N} = \frac{n_h}{n} \therefore \hat{u} = \frac{\sum n_h \overline{X}_h}{n}$$

The estimates derived from both of the groups, population and average daily operation, were very similar. However, the correlations between the number of public buildings and each grouping type show that the average daily operation had stronger correlation: correlation coefficient of population (r_2) - 0.71 compared to correlation coefficient of average daily operation (r_1) - 0.86.

Consequently, the average daily operations of small airports are used to estimate the distribution of impacted public buildings within the construction region and each state proportionally by the sampling of small airports.

7.2 Nationwide Impact

Table 7-1 shows the total nationwide impact. 1,146 buildings are impacted by aircraft noise to an extent sufficient to disrupt the normal activities occurring in those buildings. There are 738,176 impacted occupants and the total cost for soundproofing is $204,300,000. Tables 6-1 thru 6-7 in Chapter 6 provide the national impact on a regional base interior noise level.

TABLE 7-1

NATIONWIDE IMPACT

Item	Existing Building	Existing Occupants	Estimated Costs of Soundproofing * (CAT. A and B)
Schools	1057	707,370	$ 147,800,000
Hospitals and Public Health Facilities	89	30,806	56,500,000
TOTALS	1146	738,176	$204,300,000

Region	Building	Occupants
A	154	100,862
B	30	19,393
C	107	74,025
D	477	335,088
E	163	98,451
F	215	110,357
	1,146	738,176

*Include 25% markup (overhead - 10%, profit - 10%, and contingency - 5%).

CHAPTER 8

CONSULTATION AND FINDINGS

8.1 Soundproofing Views Expressed

Information was obtained on the views, opinions, and ideas expressed relative to the concept of soundproofing schools, hospitals, and public health facilities as a means of alleviating the impact of aircraft noise. These views, ideas, and opinions were volunteered.

Information obtained from school officials and hospital personnel, was obtained during telephone conversations made to collect architectural data. Additional information was obtained from FAA sponsored meetings and official briefings.

8.1.1 Consideration of Soundproofing

The facilities director of a school in Georgia said that the schools were certainly not built with aircraft noise as a consideration.

A Florida school official stated that some schools in the area have been modified to cut down on aircraft noise. The method used to improve the noise problem in these schools was the installation of air conditioning in order to keep the windows closed. No indication was given as to the effectiveness of these modifications regarding speech interference.

8.1.2 Local Interest

An official of the facilities department of a Virginia school system felt that the soundproofing program was something good and would be beneficial to the students.

Officials of school systems in New York and Louisiana stated simply that they had no interest in the soundproofing program.

During the course of the study, certain localities were found to be most interested in soundproofing. The following is a portion of a letter from one such locality:

> "Boston has been designated as a city to be included as part of the study, and the purpose of this letter is to express our desire to cooperate with you and to move ahead expeditiously. This is a subject of great importance to us and we are anxious to obtain the conclusions as to the feasibility of soundproofing . . ."

School officials in Texas and Illinois were indifferent to the soundproofing program. These officials would accept a program of soundproofing but would probably not actively seek it.

Appendix O contains a list of the source references of views expressed.

8.2 Findings

The following includes views, opinions, suggestions, and recommendations developed during the course of the study:

(a) soundproofing is a feasible technique for the alleviation of the impact of aircraft noise from an engineering and technical point of view.

(b) the noise prediction methodolgy was substantiated. This indicates that the technique of estimating the level of interior noise, and the corrective modifications to reach a pre-determined goal is a valid technique.

(c) the nationwide impact in terms of both people and buildings was estimated.

(d) soundproofing is seen as desirable and acceptable by some local authorities.

(e) establishment of a data bank which could be used as a central repository of nationwide impacted public building by jet operated airports, location, type and size, noise contour, activities, occupants, contacts, architectural and engineering plans, and all related statistics concerning populations, schools, and hospitals.

GLOSSARY

Absorption -- The dissipation of noise energy by viscous interaction at surfaces.

Absorption Coefficient -- The ratio of the sound energy absorbed by a surface to the sound energy incident upon the surface. The absorption coefficient for a given surface is a function of both angle of incidence and frequency.

Acoustical Material -- Any material considered in terms of its acoustical properties. Commonly and especially a material designed to absorb sound.

Acoustic Baffle -- A fitting in a ventilation duct which attenuates noise travelling along the duct while presenting little flow resistance.

Ambient noise -- The all-encompassing noise associated with a given environment, usually being a composite of sounds from many sources near and far.

Attenuation -- The reduction of the energy or intensity of sound. It may be due to geometrical spreading, absorption or transmission loss.

A-Weighted Scale -- A frequency weighting system that has characteristics which approximately match the response characteristics of the human ear. A-weighted levels are often referred to as dBA.

Exterior Wall Rating (EWR) -- A single number rating of the transmission loss of a construction element, representing the attenuation of A-weighted transportation noise. See Appendix B.

Frequency -- The time rate of repetition of a periodic quantity. It is usually expressed in Hertz.

Hearing Loss -- The amount by which a person's hearing is worse than normal, resulting from specific cause such as advancing age, noise exposure, or injury.

Hertz -- The unit of measurement of frequency. It is the number of repetitions per second.

Infiltration -- The leakage of air through wall panels due to incomplete sealing of joints, window frames, doors, etc.

L_{eq} -- Equivalent Noise Level, a metric for describing a time period of fluctuating noise with a single number. L_{eq} is an average level based on the average energy content of the noise. It is the constant noise level which would contain the same amount of acoustical energy as a fluctuating level for the given period. L_{eq} is always based on the A-weighted noise level. The time period over which the averaging is conducted should be specified, such as $(L_{eq})_8$ for an 8-hour period.

Level -- A scale used to describe the amplitude of acoustical quantities — usually ten times the common logarithm of the ratio of an acoustical quantity divided by a reference quantity of the same kind.

Live Room -- A room which is characterized by an unusually small amount of sound absorption.

Metric -- A measure of noise. Some metrics are complex and may account for characteristics such as noise duration, noise level, frequency content, time of occurrence, or single events.

Noise -- Annoying or unwanted sound.

Noise Level -- The sound pressure level of noise, usually A-weighted.

NR -- Abbreviation for Noise Reduction, the difference between the noise levels outside and inside a structure. Within the present study, NR is taken as the exterior A-weighted level minus the interior A-weighted level.

Octave Band -- A frequency interval whose upper and lower limits differ by a factor of two.

Sound Power Level -- Total acoustic power expressed on the decibel scale. Abbreviated PWL, this is defined as $10 \log_{10} I/I_{ref}$, where I is the acoustic power and I_{ref} is the reference power, usually 10^{-12} watts.

Sound Pressure Level -- Amplitude of sound expressed on the decibel scale, abbreviated SPL, this is defined as $10 \log_{10} (p^2/p_{ref}^2)$, where p is the root mean square acoustic pressure and p_{ref} is the reference pressure, usually 2×10^{-5} n/m^2.

Pure Tone -- A sound in which the sound pressure changes sinusoidally with time.

Radiation -- The process of turning structure-borne noise into airborne noise.

Reverberation -- The persistence of previously generated sound caused by reflection of acoustic waves from the surfaces of enclosed spaces.

Shielding -- With respect to buildings, the tendency of the portions of a structure facing a noise source to attenuate the noise before it reaches portions of the structure not facing the noise source. The shielding building faces can be thought of as creating an "acoustical shadow".

Sound Insulation -- (a) Measures taken to reduce the transmission of sound, usually by acoustical materials; (b) the property of a partition that opposes the transmission of sound from one side to the other.

AD-A069 702 TRANS SYSTEMS CORP VIENNA VA F/G 1/5

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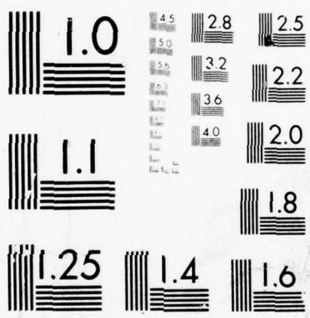

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

GLOSSARY (Concluded)

Sound Level Meter -- An instrument for the direct measurement of sound pressure level. It consists of a microphone, an amplifier, a calibrated attenuator, and a display to indicate the measured sound levels. Various frequency weighting networks, such as A-weighting, are often incorporated.

Structure-Borne Noise -- A condition when the sound waves are being carried by a solid material. Airborne noise can be created from the radiation of structure-borne noise into the air.

STC -- Abbreviation for Sound Transmission Class, a single number rating of the transmission loss of an interior construction element, representing the attenuation of A-weighted interior noise.

TL -- Abbreviation for Transmission Loss, the attenuation (in decibels) of sound transmitted through a panel. In general, TL is a function of frequency.

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APPENDIX A

TECHNICAL SUPPORTING INFORMATION FOR DEFINITION OF THRESHOLD LEVELS OF NOISE EFFECTS

The data presented in this Appendix provides the technical background information required to support selection of the threshold levels of noise effects specified in Chapter 2.

The adverse effects of noise on people can be grouped into three general categories: degradation of health, behavioral reactions, and activity interference.[A-1] The characteristics of the noise impact related to each of these categories is discussed in the following pages. Interference with noise-sensitive activities occurs for lower levels of noise exposure, and was therefore chosen as the basis for defining threshold noise levels for this report.

A-1 Physical Health Effects

Adverse physical health effects from noise exposure occur in three forms: hearing damage, physical pain or injury, and physiological reaction. The immediate physical sensation of discomfort due to noise generally occurs above 120 dB, while auditory pain occurs somewhere between 135 and 140 dB, and actual immediate injury for unprotected ears at levels above 150 dB.[A-1,A-2]

The levels associated with hearing damage due to accumulated exposure to noise cover a large range reflecting the variation of individual susceptibility to such exposure. Levels specified as criteria for hearing protection vary greatly because of this and because of the intended degree of protection. The Occupational Safety and Health Administration regulations limit 8-hour workplace noise exposure to a maximum of 90 dBA.[A-3] This level represents protection against long-term hearing disability. At the opposite extreme, Kryter[A-2] has reported that 8-hour level of 65 dBA will result in little or no hearing loss in at least 75 percent of people. Higher levels can be tolerated for shorter times, and total exposure is probably best represented in terms of total acoustic energy. In a review of hearing loss information, the United States Environmental Protection Agency[A-4] has identified an 8-hour L_{eq} of 75 dBA as an appropriate level to protect against hearing loss.

Various physiological responses to noises have been noted and measured. These are in the nature of involuntary stress reactions which could lead to long-term health problems. These physiological responses, however, are reported not to be measurable for A-weighted sound levels below about 70 dB.[A-2, A-5, A-6, A-7] It is commonly held that long-term adverse non-auditory health effects will not occur if exposure to noise is less than the exposures recommended to prevent hearing loss.[A-1,A-4,A-5,A-6]

A-2 Psychological and Behavioral Reactions

Psychological or behavioral reactions to noise exposure are of two types: interference with the performance of non-auditory tasks, and general annoyance.

A-2.1 Task Performance

Although there are little and somewhat conflicting data reported concerning the performance of non-auditory tasks in the presence of noise, some conclusions about this effect can be made. For steady noises, interference with non-verbal task performance does not occur for A-weighted levels below 90 dB.[A-1,A-4,A-5,A-6] However, levels below 90 dB may have an effect if the noises are intermittent, unexpected, uncontrolled, or contain predominantly high frequencies.[A-4,A-5,A-6,A-8] As a lower bound to prevent task interference for any type of noise, Kryter[A-2] suggests an A-weighted level of about 70 dBA. It should be noted that all the reported threshold levels for task interference are well above those identified for speech and sleep interference.

A-2.2 Annoyance

Unlike the adverse hearing and physiological effects of noise discussed above, threshold levels for annoyance cannot be separated from those identified for activity interference. Results of studies which attempt to determine annoyance indicate that although annoyance may occur for a variety of reasons (and is highly subjective), interference with some activity, particularly those associated with communication, are quite important in causing the subjective reaction of annoyance.[A-4,A-5,A-6,A-9,A-10] Intrusion levels identified from interference considerations often agree with levels identified from annoyance reaction.[A-11] Due to the link between activity interference and annoyance and to the degree of subjectivity associated with annoyance, it was decided not to directly consider annoyance in the specification of threshold levels for schools and hospitals. However, because of this link, it can be concluded that noise levels sufficiently low to produce no activity interference will probably produce little or no annoyance.

A-3 Activity Interference

As developed in this section, interference with noise-sensitive activity generally occurs at a lower level than other adverse effects of noise. For this reason, activity interference was chosen as the basis for defining the noise impact on occupants of public buildings due to aircraft operations. The following sections provide a discussion of the technical aspects of noise interference and the rationale used for identification of realistic threshold levels for noise effects on occupants of schools, hospitals and public health facilities near airports.

A-3.1 Speech Interference in Schools

The primary activity sensitive to noise intrusion for schools is speech communication. In addition to the requirement for the physical reception and recognition of spoken sounds, provision of a noise environment which does not interfere with this activity is important for two other reasons:

1. A noise environment which is conducive to learning is required. After review of the latest research concerning noise and learning for children, Mills[A-13] concludes that a noise environment which would cause speech interference for adults would be sufficient to interfere with the learning process for children particularly in the development of communication skills.[A-9]

2. The short-term disruption of the classroom causing direct results such as loss of flow of lessons. In a recent survey of teachers in schools exposed to aircraft noise from London Airport (Heathrow),[A-9] it was found that the interference with verbal communication and the resulting disruption was the most often cited nuisance of aircraft noise intrusions. The disruptive effects of periods of communication interference on the daily educational process in the classroom has also been recently cited by Miller.[A-5]

Aspects of Verbal Communication

Interference with speech communication in the presence of background noise is governed by the speech spectrum level at the listener's ear and by the spectrum level of the background noise. Some frequencies are more important to speech reception than others, so that the overall speech interference is determined by the signal-to-noise ratio as a function of frequency. The spectrum level of speech at the listener's ear is dependent on the spectral characteristics and voice effort of the speaker and the propagation of the signal between the speaker and listener. For typical indoor speech communication, this propagation is governed by the distance between speaker and listener and the reverberation in the room.[A-14]

The Articulation Index (AI) was developed by French and Steinberg[A-15] as an estimate of speech interference by noise based on the speech and background noise level at a listener position. As originally developed, AI indicates approximately the degree to which the background noise penetrates into the range of levels of the speech signal in 20 frequency bands contributing equally to AI. The method of AI determination has since been further developed to allow calculation using octave or 1/3 octave frequency band widths.[A-16,A-17] These procedures are published as ANSI Standard S3.5.[A-18]

Numerous studies have been conducted to relate speech interference as specified by AI to various measures of intelligibility.[A-2] These studies typically consider the percentage of words or sentences correctly perceived in a given level of speech and interfering noise for normal adults familiar with the language.[A-2,A-12] Generally, for a given AI, word comprehension is less than sentence comprehension due to the redundancies exhibited in normal speech.

There are two qualitative considerations which must be made when applying noise criteria based on speech intelligibility to classroom situations. First, children are not as familiar with language as adults and hence may miss some of the verbal cues and redundancies which aid adults in communication. For this reason it has been concluded that background noise levels should be lower for children to achieve the same level of speech comprehension as adults.[A-5,A-6,A-13,A-19,A-20] Second, communication quality cannot be judged entirely on the basis of intelligibility.[A-21,A-22] Nagel[A-22] has concluded that the effectiveness of communication can be adversely affected even by noise levels which allow perfect intelligibility. This phenomenon occurs because the effort required to process speech information in the presence of background noise increases with levels of this noise although perfect intelligibility can be maintained.

While there is no quantitative adjustment available for these last two factors, in practice they can be accommodated (albeit somewhat arbitrarily) by selecting a slightly conservative intelligibility criterion.

Speech Interference Level

Using the concepts of AI, the speech interference level (SIL) concept was developed by Beranek[A-23] as a simplified alternative to AI. The SIL as originally defined is the arithmetic average of the levels of the background noise in three octave bands important to speech communication. The relationship of this background noise measure was originally developed for speech communication in aircraft by Beranek and Rudmose[A-24] and later elaborated further by Beranek.[A-25] As a result of this work, a table of maximum SIL's for which "satisfactory" speech intelligibility in aircraft cabins would be obtained for average male voices was developed. The maximum SIL values were given as a function of speaker-listener separation with vocal effort as a parameter. This table has since been displayed graphically and appears frequently in the literature in several forms.[A-2, A-4, A-5, A-6, A-19, A-20, A-26, A-27, A-28] The extension of this original work to include subjective evaluation of the corresponding SIL, the addition of "communicating" and "expected" voice levels, and the conversion to other measures of noise such as A-weighted sound level and perceived noise level has recently been reported by Webster.[A-26] Although the various forms of this basic speech interference prediction by Beranek[A-23] are widely reported, caution must be exercised in their use for purposes of this report as they are based on an AI of about 0.4. This value of AI corresponds to approximately 85 percent correct sentence and 62 percent phonetically balanced word reception for average adults.[A-18]

Requirements for Classrooms

The Articulation Index method was used to evaluate the noise environment requirements for classrooms. This method was chosen in order that speech level, room characteristics, and noise level of the intrusion could all be properly incorporated in the determination of required environment. To use AI, it is first necessary to establish the average sound level of the speech signal at the receiver. For this purpose, normal female voice spectrum levels compiled by Kryter[A-2] were used. For the classroom environment, it was assumed that instructors would typically use a raised voice adding about 6 dB to normal voice level.[A-2,A-25] To project the voice level from the reference free-field specification, some characteristics

of the classroom must be assumed. Although physical classroom characteristics may vary considerably, a maximum speaker/listener separation of 9 meters (29.5 feet) and a total room absorption of 600 sabins (English units) were assumed. These assumed parameters agree well with those determined in the measurement portion of this program as well as with average values reported elsewhere.[A-29,A-30,A-31] It should be further noted that the voice level at the listener is only slightly affected by these assumed values as the 9 m position is well within the reverberant field of the room,[A-30] and a range of 300 to 1,000 sabins corresponds to only a 2.7 dB variation in speech level at 9 meters from a speaker. Using the speech level data and the assumed room characteristics, the average speech level at a 9 m listener position was determined. The A-weighted level of the projected speech signal was 61.6 dB at 9 m which compares quite well with the measured average speech A-weighted level of 62 dB at 7 m recently reported by Pearsons.[A-32]

Another requirement for use of AI in the specification of a communication environment is the relative spectrum level of the interfering noise. For this purpose, an average outdoor aircraft noise spectrum combined for takeoff and landing operations was used to obtain the relative octave band spectral shape.[A-33] This shape was then modified for use indoors by application of average exterior to interior noise reduction data in octave bands (Appendix N of Reference A-34).

Using the above information and the procedures for determination of AI from octave band data as specified by ANSI S3.5,[A-18] the relationship between indoor A-weighted sound level and resulting AI was calculated. This relation was shown in Figure 2-2 of Chapter 2.

The relation between AI and A-weighted noise falls into two ranges, each approximately a straight line. At levels below the transition at 45 dBA, where AI = 0.98, very small gains in AI would be obtained for large reductions in level. This value of AI produces for average adults correct recognition of 100 percent of first-presented sentences and 98 percent phonetically balanced (PB) from a 1,000-word list. Since intelligibility is not perfect, there is clearly some interference at this level. Intelligibility is very good at this level, however, so that in view of the marked change in slope at lower levels it would not be reasonable to establish a criterion at a lower level. We therefore identify a level of 45 dBA as the threshold level for speech interference.

As discussed previously, the characterization of the noise environment in the classroom depends both on the intensity of each intrusion and frequency with which they occur. However, given that the noise level of 45 dBA is a threshold at which interference with the speech activity will begin, it can be compared to steady-state sound levels previously recommended for classrooms. These A-weighted noise levels range from 35 to 50 dB.[A-2,A-4,A-5,A-6,A-19,A-28,A-30,A-36,A-37,A-38] Further, it can be shown that the equivalent PNC of the identified A-weighted level is about 38 dB. This compares with PNC values recommended by Beranek, Blazier, and Figwer for classrooms of 30 to 40 dB.[A-35]

Although the noise level of 45 dBA has been identified as that level at which communication interference due to aircraft noise will begin in classrooms, assessment of the noise environment of any given classroom also depends on the existing background noise in the absence of aircraft noise. Recent noise measurements in 72 classrooms in the

absence of aircraft noise and verbal communication indicated levels from 42 to 67 dBA.[A-39] While much of the measured noise may be attributable to sources which would stop while a teacher is speaking (students talking, shuffling feet, etc.), background levels during instruction could fall within this range. When selecting an aircraft noise criterion for a classroom, the actual background level as well as the threshold of 45 dBA must be considered as a lower bound.

A-3.2 Sleep Interference in Hospitals

Because sleep may be crucial to patient recovery, and is a critical activity for patients in hospitals, interference with sleep is the criterion used in the consideration of the noise environment of hospitals. Although research has been done on the immediate effects of noises, the link between sleep disturbance and well-being has not been demonstrated quantitatively even though adverse effects of sleep disturbance are postulated by many sleep investigators.[A-2,A-5,A-13] Indirect evidence of this assertion is afforded by surveys of community reaction to aircraft noise which indicate that sleep interference is a significant contributor to general annoyance.[A-4] Although there has been some recent research which indicates that people may adjust to sleeping in intrusive aircraft noise environments over a period of years,[A-40] no such adaptation would be expected during a short period of hospitalization.

Sleep Disturbance From Noise Exposure

There has been a number of studies reported which relate sleep disruption and awakening to steady and intermittent noises. In a compilation of recent data, the U.S. Environmental Protection Agency[A-19] found that for steady noises, sleep disturbance begins when the noise level reaches about 35 dBA. In a study of sleep awakening due to steady noise, Grandjean[A-41] found that a sound level corresponding to a noise level of 36 dBA produced awakening in 10 percent of his subjects.[A-42] The EPA compilation of sleep data also indicated that single event maximum levels of 40 dBA result in a probability of awakening of 5 percent and that maximum levels of 70 dBA result in a 30 percent probability of awakening.[A-19] Using recordings of noise produced by passing trucks, Thiessen found that 10 percent of his subjects either shifted to a shallower stage of sleep or awakened for maximum levels between 40 and 45 dBA.[A-43] Thiessen further found similar response in 50 percent of his subjects for a maximum level of 50 dBA.[A-42] Also for aircraft noise approximated by the (A-weighted) Sound Exposure Level (SEL), Lukas[A-44,A-45] determined that sleep disruption occurs at a rate of about 5 to 10 percent for an SEL of 52 dB. Although Lukas[A-40,A-45] states that the highest correlation between sleep disruption and noise exposure exists when both intensity and duration are taken into account, the maximum A-weighted level corresponding to this SEL can be approximated. If a 20-second duration between 10 dB down points of the flyover event is assumed, the corresponding maximum level producing 5 to 10 percent disruption is about 42 dBA.

As will be noted from review of above data, there is some variation in the response level associated with given noise levels. This variation is likely a result of differences in age of subjects, background noise level during the experiment or other parameters which

may affect the results but were not always reported. To simplify this situation, Lukas[A-46] has recently estimated the degree of sleep interference for various single event A-weighted maximum sound levels based on a composite of the reported laboratory data through 1975. The results of this determination were presented in Figure 2-3 of Chapter 2.

Requirements for Hospitals

To define interference with the sleep activity in hospitals, the level at which awakening begins to occur was considered as the level corresponding to the beginning of interference. This criterion was chosen due to the lack of data relating sleep disruption without awakening to physical and psychological well-being. Applying this criterion to the data shown in Figure 2-3 of Chapter 2, the threshold level for interference with the activity of sleeping is 40 dBA.

As with the case of classrooms, characterization of the noise environment in hospitals depends on the intensity of each intrusion and the frequency of their occurrence. However, as with classrooms, the threshold level of 40 dBA identified above can be compared to various other recommended interior sound levels for hospitals and sleeping environments. For steady noises the recommended interior noise levels for hospitals range between 34 and 47 dBA.[A-2,A-30,A-35,A-38] For further comparison, in a previous review Wyle[A-42] concluded that interior noise levels above 45 dBA are likely to cause sleep disturbance for a significant percentage of the population.

Characterization of the noise environment in any specific hospital is dependent on background levels in the absence of aircraft noise as well as on the intensity, duration, and rate of occurrence of aircraft noise intrusions. Background noise levels in patient rooms of eight hospitals have been measured and reported.[A-47] The results of this study indicated that the background noise level ranged from 35 to 60 dBA with the average level for 24 hours being typically between 40 and 45 dBA.[A-47]

A-4 Summary

Based on the literature cited in this review, interior levels which define the approximate threshold of noise effects of people from aircraft noise have been estimated for schools, hospitals and public health facilities. The A-weighted sound levels defining these thresholds are:

Schools	L_A	= 45 dBA (Speech Interference)
Hospitals (and Public Health Facilities)	L_A	= 40 dBA (Sleep Interference)

These identified values define those noise levels below which interference by the noise is not expected to occur. While lower levels have been suggested in some cases by others as desired design goals for new schools and hospitals, these are not supported by the literature. It is believed that the above levels represent realistic measures of the desired thresholds which are supported by the literature.

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APPENDIX B

DEVELOPMENT OF THE EXTERIOR WALL RATING (EWR)

B-1 Exterior-Interior Noise Reduction

The following procedure can be employed to obtain an expression describing the exterior-to-interior (outdoor-to-indoor) noise attenuation of a building structure.

For an exterior single-frequency sound source and a reverberant receiving room, the sound intensity incident at the location of an exterior wall of the receiving room, assuming a free progressive plane wave, is

$$I_1 = \frac{p_1^2}{\rho c} \tag{B-1}$$

where p_1^2 = The exterior free-field mean square sound pressure;

ρc = The acoustic impedance of air.

The power which will be radiated into the receiving room by the wall is

$$W = \tau I_1 S = \tau \left(\frac{p_1^2}{\rho c} \right) S \tag{B-2}$$

where τ = The transmission coefficient of the wall at the source frequency;

S = The surface area of the wall exposed to the noise source.

The steady-state reverberant intensity in the receiving room, assuming a perfectly diffuse field, will become

$$I_2 = \frac{W}{A} = \frac{p_2^2}{4 \rho c} \tag{B-3}$$

where A = The total absorption in the room at the source frequency;

p_2^2 = The reverberant space-averaged mean square sound pressure in the receiving room.

Substituting the value of W from Equation (B-2),

$$\frac{\tau p_1^2 S}{\rho c A} = \frac{p_2^2}{4\rho c} \quad \text{or} \quad \frac{p_1^2}{p_2^2} = \frac{A}{4\tau S} \tag{B-4}$$

If 10 times the $\log_{10}$ of each side of Equation (B-4) is taken,

$$10 \log_{10} \frac{p_1^2}{p_2^2} = 10 \log_{10} \frac{1}{\tau} + 10 \log_{10} \frac{A}{S} - 6, \text{ dB} \tag{B-5}$$

Now in general, sound pressure level is defined as

$$SPL = 10 \log_{10} \frac{p^2}{p_{ref}^2}, \text{ dB}$$

where p^2 = The mean square sound pressure;

p_{ref} = A reference pressure.

Thus,

$$SPL_1 - SPL_2 = 10 \log_{10} \frac{p_1^2}{p_{ref}^2} - 10 \log_{10} \frac{p_2^2}{p_{ref}^2} = 10 \log_{10} \frac{p_1^2}{p_2^2}, \text{ dB} \tag{B-6}$$

Defining transmission loss as

$$TL = 10 \log_{10} \frac{1}{\tau}, \text{ dB} \tag{B-7}$$

Substituting Equations (B-6) and (B-7) into (B-5),

$$SPL_1 - SPL_2 = TL - 10 \log_{10} S/A - 6, \text{ dB} \tag{B-8}$$

where SPL_1 = The free-field exterior sound pressure level which would exist, in the absence of the transmitting wall, at the wall's exterior surface;

SPL_2 = The average interior sound pressure level in the receiving room;

TL = The transmission loss of the wall at the frequency under consideration;

S and A = Defined earlier.

This difference between the free-field exterior sound level and average interior sound level is referred to as the noise reduction of the room or structure.

Equation (B-8) gives the noise reduction of a uniform structure only for a single-frequency or narrow-frequency band of sound since transmission loss and absorption are frequency dependent. Thus, calculation of the noise reduction in overall sound level provided by a structure for broad band incident sound would require knowledge of the spectral levels of the incident sound, multiple calculations of spectral noise reduction, and combination of the resulting spectral interior levels into a single broad band interior sound level. To simplify this process, a single number transmission rating which synthesizes the spectral TL values into one number indicative of the broad band transmission characteristic of a structure would be desirable. If, in addition, frequency-independent values could be used for the $10 \log_{10} (S/A)$ term, an equation in the form of Equation (B-8) could be used to calculate the broad band noise reduction of a structure in a single step.

A rating which approximates the broad band transmission characteristics of structures, called External Wall Rating (EWR), has been developed for this type of application to calculate outdoor-indoor noise reduction of incident A-weighted sound levels.[B-1] In addition, data were obtained in this program which show that typical values of total broad band interior absorption for the types of rooms encountered in this study are nearly frequency independent. This same insensitivity of interior absorption with frequency was observed for tests in over 100 rooms in residences.[B-2] These two developments allow application of the following equation:

$$SPL_o - SPL_i = NR = EWR - 10 \log S/A - 6 - C, \quad \text{dB} \qquad \text{(B-9)}$$

where NR = Difference between (1) the free-field A-weighted sound level which would exist, in the absence of the structure, at the structure exterior surface (SPL_o), and (2) the average interior A-weighted sound level (SPL_i);

EWR = External Wall Rating;

S = Transmitting surface area;

A = Typical interior absorption value;

C = A constant which is a function of the source spectrum and is described later in Section B-2.4.

Note that Equation (B-9) applies only to a single homogeneous structure.

B-2 Development of EWR Rating Scheme

B-2.1 EWR Concept

In developing a single number EWR rating, two basic principles were employed: (1) restrict the outdoor noise spectrum to a constant shape varying only in level, and (2) approximate the actual transmission curve for a structure in terms of an ideal TL curve which would filter the outdoor spectrum such that the resulting interior spectrum has the inverse shape of the A-weighting curve. Then when the interior spectrum is A-weighted, each one-third octave band would contain equal energy and therefore be equally important in determining the interior A-weighted noise level. This facilitates the prediction of interior A-weighted noise levels and noise reduction.

The problem is conceptualized in Figure B-1. Consider, for the moment, that the exterior noise spectrum exhibits a shape similar to that shown in the figure. As will be discussed, this, in fact, is the nominal average spectrum for the typical source noise. It is desired, then, that the transmission loss characteristic of the wall act as a shaping "filter" to the prescribed exterior noise spectrum so as to produce an interior noise spectrum similar in shape to the inverse of the A-weighted response curve. Interior absorption, having been shown to be independent of frequency,* will not affect the shape of the interior noise spectrum.

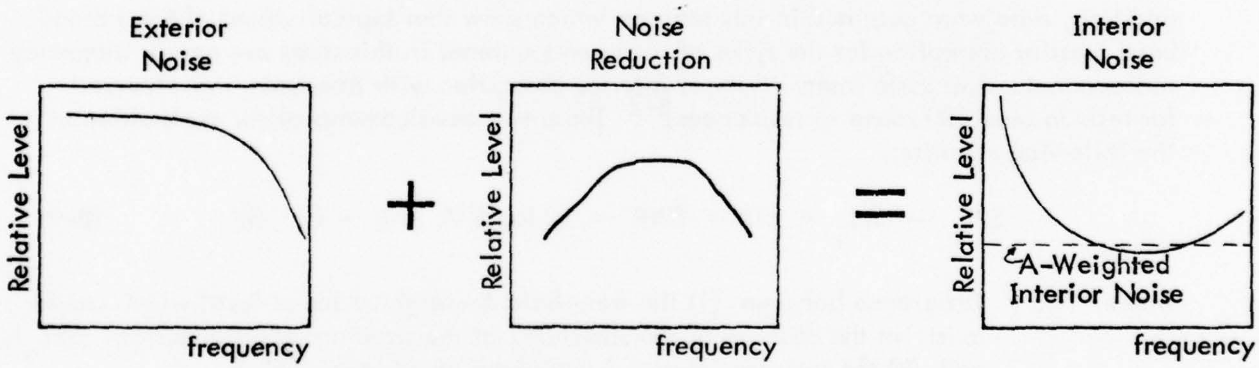

FIGURE B-1. CONCEPTUAL ILLUSTRATION OF BASIS FOR STANDARD TL CURVE FOR EWR CONCEPT

To identify the precise shape of this standard transmission loss curve, an assumption must be made as to the frequency characteristics of the incident exterior noise. For the initial development of EWR, the characteristics chosen were those of highway traffic noise. Figure B-2 presents the typical range of highway spectra averaged over a 24-hour period for a single location near a heavily travelled freeway. Using these data, the nominal average spectrum for highway noise was calculated, with the results illustrated in Figure B-3. Note that the octave band levels are relative to the overall energy-average A-weighted sound level.

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* See Section B-1.

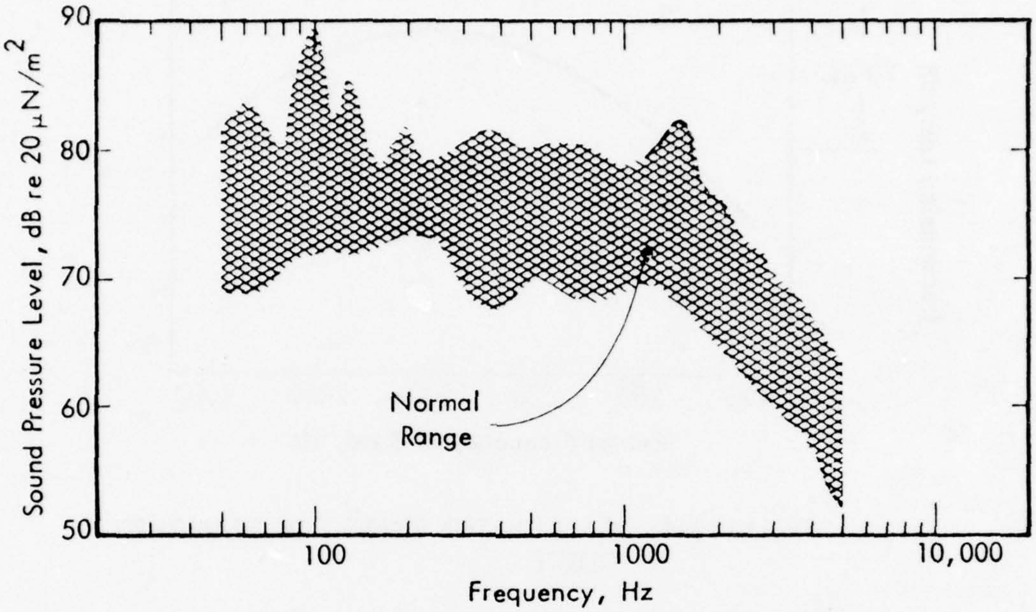

FIGURE B-2. TYPICAL HIGHWAY NOISE SPECTRA[B-3]

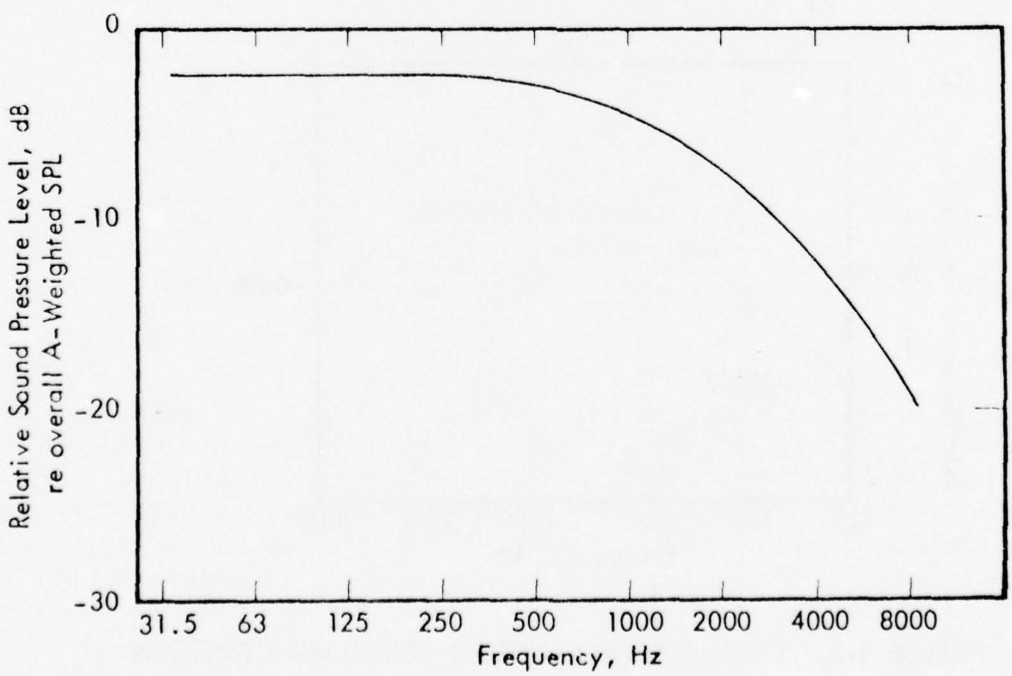

FIGURE B-3. STANDARD HIGHWAY NOISE SPECTRUM

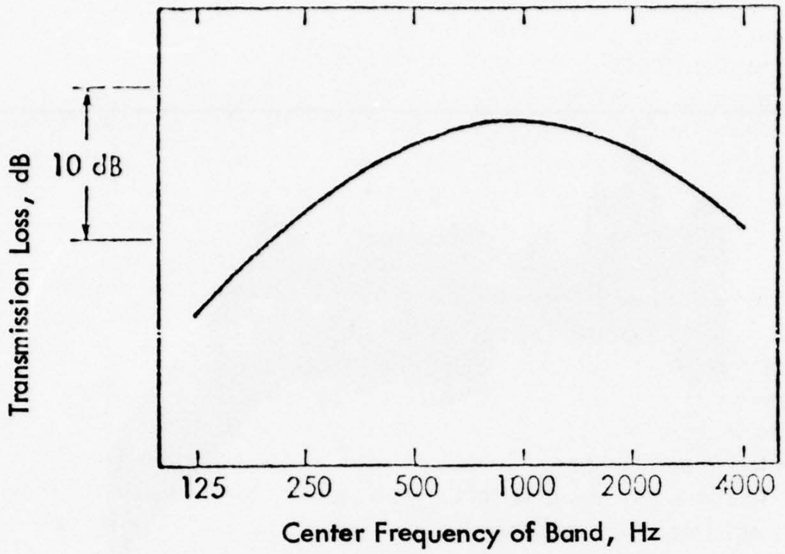

FIGURE B-4. CALCULATED SHAPE FOR STANDARD CURVE

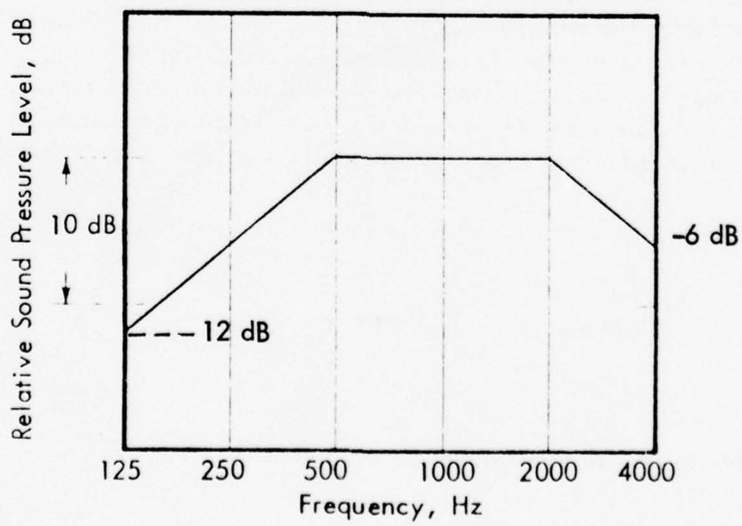

FIGURE B-5. EXTERIOR WALL RATING STANDARD CONTOUR

Knowing the characteristics of the exterior noise spectrum, the shape of the special transmission loss curve shown in Figure B-4 was computed according to the concepts of Figure B-1. Several straight-line approximations to the curve were investigated and the curve shown in Figure B-5 was chosen as the EWR standard contour. This contour can be used in a manner similar to an STC contour to determine the EWR rating for a given wall or construction element based on its TL curve. To do this, the standard contour is adjusted vertically to the highest position relative to the TL curve until, over the frequency range of 125 to 4000 Hz, the sum of the deficiencies in the 16 one-third octave bands (that is, deviations of the TL curve below the contour) is 32 or less. The EWR is then arbitrarily taken as the value of the standard curve level at 500 Hz.

The fact that the actual EWR value is arbitrarily taken as the level of the EWR contour at 500 Hz implies that an EWR value obtained using the above procedures may require final adjustment by a constant to better approximate the reduction in A-weighted noise levels for the structure. Also, EWR values assume an incident noise frequency spectrum similar to that of typical highway noise. Therefore, the spectral shape of the EWR standard contour, and hence actual EWR values, are dependent upon this highway noise spectrum. To use EWR values for predicting building attenuation of aircraft noise, which has a different frequency spectrum, an additional correction will be needed. These adjustments are those labelled "C" in Equation (B-9), and are developed further on in Section B-2.4 of this Appendix.

B-2.2 EWR for Composite Structures

When a structure is composed of several different transmitting elements, the transmission loss of the composite structure must be determined. Standard procedure first entails calculating the composite transmission loss in each one-third octave band. Then a single number rating such as EWR may be determined from this composite transmission loss curve. However, the results of sample calculations* indicate that a composite EWR value may be determined with little error by obtaining the EWR of each structure element and combining these values independently of frequency as shown below in the same fashion as is normally used to compute composite transmission loss:

$$EWR_{composite} = 10 \log_{10} \frac{\sum_i S_i}{\sum_i \tau_i' S_i} , \quad dB \qquad (B-10)$$

where i = Index for the transmitting structure elements;

S_i = Surface area of the i'th element;

τ_i' = The transmission coefficient of the i'th element corresponding to the EWR of that element (EWR_i), or:

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* See Section B-2.4.

$$\tau_i' = 10^{-EWR_i/10} \tag{B-11}$$

Now if Equations (B-10) and (B-11) are substituted into Equation (B-9), the following general expression may be defined for the EWR of a composite structure to predict noise reduction of A-weighted sound levels:

$$NR = SPL_o - SPL_i = -10 \log_{10} \sum_i S_i \, 10^{-EWR_i/10} + 10 \log_{10} A - 6 - C, \text{ dB} \tag{B-12}$$

where C represents the source-critical adjustment constants described in the previous section.

B-2.3 <u>Calculation of the Tabulated EWR Values</u>

The EWR values tabulated for the various construction elements used in this report were calculated using a computer algorithm which simulates the standard EWR contour-fitting technique described in Section B-2.1. The transmission loss curves used for the contour-fitting exercise were obtained in one of two ways.

Transmission loss data used for determining wall and roof-ceiling EWR values were calculated using a second computer algorithm based on the transmission loss theory presented in a recent U.S. Department of Housing and Urban Development report.[B-4] This theory allows calculation of TL values assuming the existence of significant acoustical absorption in studwork walls, in furred walls, and in single-joist roof-ceilings. Since EWR values for building elements without absorption were desired, negative EWR adjustments to account for the effects of the insulation were required. These adjustments were obtained from an extensive literature search for transmission loss values of all types of building exterior constructions. Comparative EWR analyses using numerous TL data for walls and roof-ceilings with and without absorption resulted in absorption corrections of minus 4 dB for studwork walls, minus 3 dB for furred walls and minus 5 dB for single-joist spaces. These corrections were applied to the calculated EWR values yielding the values tabulated at the end of the Appendix.

Transmission loss values used for determining the EWR of windows, doors and air conditioners consisted of published measurement data collected during the literature search. No special adjustments were required before placing the resulting EWR values in the tables.

It should be noted that the EWR values tabulated for walls and roof-ceiling constructions were calculated ideal values which would not be completely achieved by standard construction techniques due to the usual presence of gaps, leaks and flanking paths. The literature search data indicated that the average reduction of these ideal values due to the

imperfections of actual standard extension construction is about 4 dB. EWR values tabulated at the end of this Appendix for the other construction elements are based on the measured performance of standard construction. The values given in the EWR adjustment tables, used to adjust the EWR of basic structures to account for the effects of detail modifications, were also obtained from comparative analyses using data from the literature.

B-2.4 EWR Accuracy and Regression Constants

The most important criterion for application of EWR to this study is that it should give better accuracy in calculating the interior A-weighted noise level for a variety of exterior wall structures than any other single number rating scheme. To evaluate the accuracy of EWR for the prediction of structure noise reduction of incident aircraft noise, a large-scale comparison was made between noise reduction based on EWR and a more accurate noise reduction calculated in a classical manner with TL values at each frequency band. That is, the exterior noise level spectrum for aircraft shown in Figure B-6 was applied along with frequency-dependent transmission loss data for many commonly used exterior walls to predict interior spectra. These spectra were then A-weighted to determine an accurate interior A-weighted noise level for each wall type. The EWR of each wall was also determined and applied to the exterior A-weighted level to obtain an estimate of the interior A-weighted noise level according to Equation (B-12). A linear regression analysis was then conducted to determine the correlation between the two resulting interior levels. Note that the absorption term (A) and constants in the noise reduction Equation (B-12) are independent of frequency and would not have any effect on the regression outcome since they would have been applied equally to both noise level calculations. Thus they were not required in the calculations. Combinations of 225 wall constructions and 33 window constructions in area ratios of 0, 10, 15 and 20 percent of total wall area were used for a total of 22,500 separate cases. In each case, interior levels based on composite octave band transmission loss values and on composite EWR values were determined.

The aircraft noise spectrum of Figure B-6 used in this comparison was derived from sound level measurements of commercial aircraft operations. Two noise measurements were utilized — one under the landing path and one under the takeoff path located approximately within the NEF 40 contour at Los Angeles International Airport. Approximately one hour of data was reduced for each site and the energy-equivalent noise level in each octave band was determined. These were time-averaged spectra which were dominated by the noise spectra of the aircraft flyovers. The frequency spectra for takeoff and landing were similar in shape (both decreasing in level with increasing frequency) so they were combined into the single average aircraft noise spectrum shown in Figure B-6.

An initial linear regression analysis was carried out using each pair of interior A-weighted noise levels calculated using (1) the classical method with TL values for each frequency band, and (2) the approximate single number method with EWR. Since the slope of this regression was very close to unity, an additional regression forcing the slope to be unity was performed. A conceptual illustration of this regression is shown in Figure B-7. The correlation coefficient for the unity slope regression is about 0.98 and the 90 percent

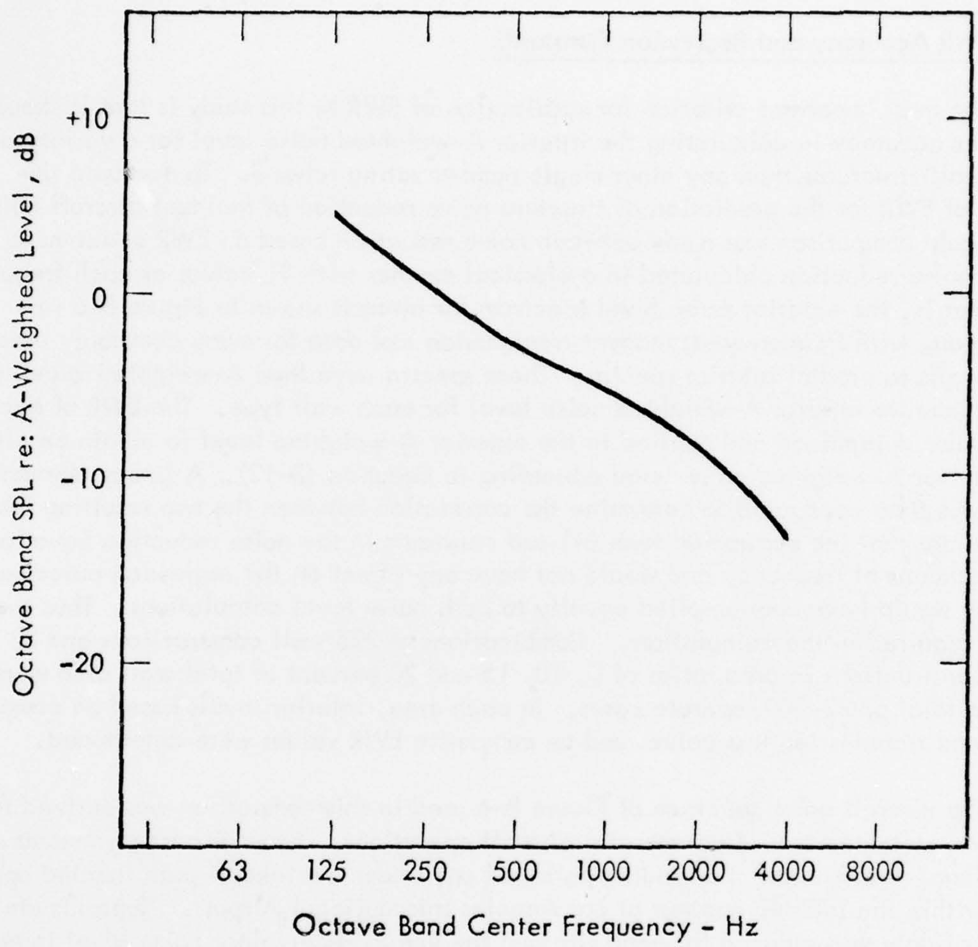

FIGURE B-6. AIRCRAFT NOISE SPECTRUM

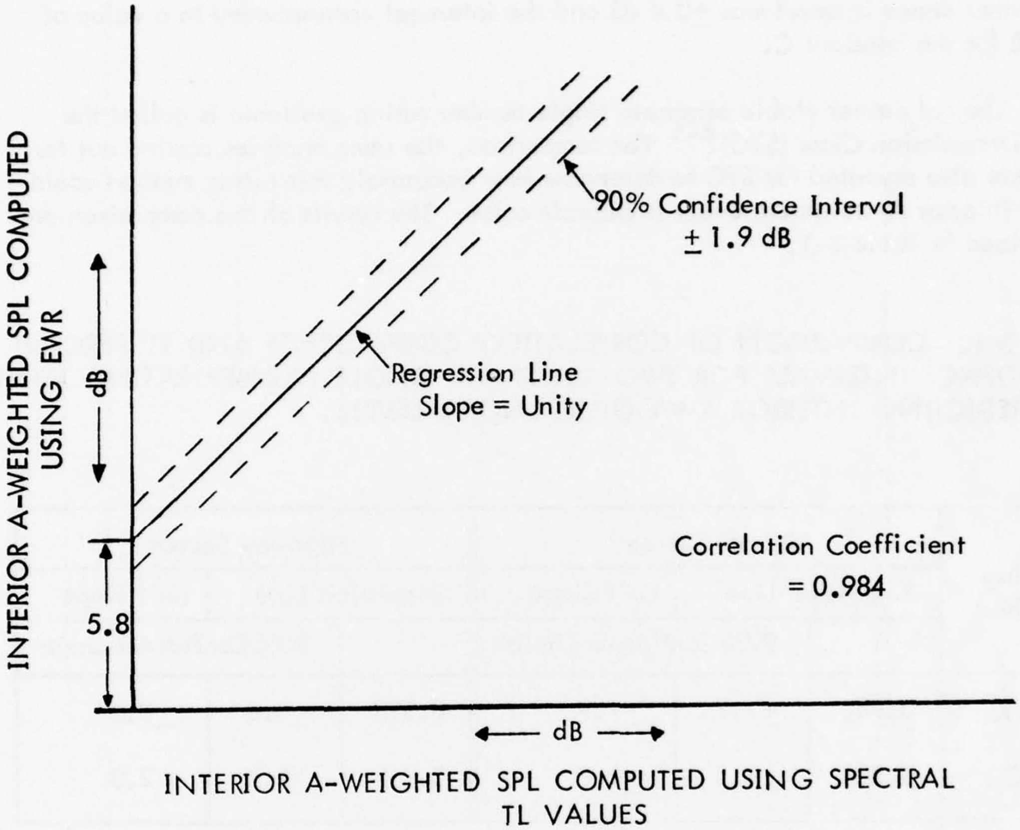

FIGURE B-7. CONCEPTUAL ILLUSTRATION OF REGRESSION ANALYSIS RESULTS COMPARING INTERIOR A-WEIGHTED NOISE LEVELS FOR AIRCRAFT COMPUTED WITH THE SINGLE NUMBER EWR METHOD OR WITH THE CLASSICAL TL METHOD AT EACH FREQUENCY BAND.

confidence interval (calculated based on the assumption that the overall distribution was gaussian) is less than ±2 dB. As illustrated, the regression line has an intercept of ±5.8 dB for this case of aircraft noise as a source so the constant C in Equation (B-12) is -5.8 dB for this source. A similar regression analysis was performed using the highway noise spectrum shown earlier in Figure B-3. Applying the same technique of a forced unity slope, the 90 confidence interval was ±0.6 dB and the intercept corresponded to a value of -3.5 dB for the constant C.

The only other viable alternate single number rating available is called the Sound Transmission Class (STC).[B-5] For comparison, the same analyses carried out for EWR were also repeated for STC to determine how accurately this rating method could predict interior A-weighted levels of aircraft noise. The results of this comparison are summarized in Table B-1.

TABLE B-1. COMPARISON OF CORRELATION COEFFICIENTS AND 90 PERCENT CONFIDENCE INTERVALS FOR TWO ALTERNATE SINGLE NUMBER RATING METHODS FOR PREDICTING INTERIOR A-WEIGHTED NOISE LEVELS.

Rating Method	Aircraft Source			Highway Source		
	Regression Line		Unit Slope	Regression Line		Unit Slope
	r	90% Confidence Limits		r	90% Confidence Limits	
EWR	0.984	±1.7	±1.9	0.998	±0.6	±0.6
STC	0.926	±3.5	±3.9	0.962	±2.7	±2.8

The 90 percent confidence limits for the STC method are approximately twice (about ±4 instead of ±2) that for the EWR method for an aircraft source. The EWR method should therefore be somewhat more reliable for application to this program. Actual measurements of outdoor-indoor noise reductions for A-weighted noise levels carried out in this program were also shown to agree satisfactorily with predicted values based on the use of EWR (see Appendix G).

In summary, throughout this study Equation (B-12) was used to estimate interior A-weighted noise levels for predictive analyses. The tabular values of EWR and the corresponding adjustment factors are listed in Tables B-2 through B-7.

TABLE B-2a. EXTERIOR WALL RATING (EWR) VALUES FOR EXTERIOR CONSTRUCTIONS*

EXTERIORS	INTERIORS	1 1/2" Gypsumboard	2 3/8" Gypsumboard	3 2 layers 1/2" Gypsumboard	4 2 layers 5/8" Gypsumboard	5 3/8 Gyp Lath/1/2" Plaster	6 3/8 Gyp Lath/1/8" Plaster	7 1/2" Soundboard/ 1/2" Gypsumboard	8 1/2" Soundboard/ 3/8" Gypsumboard	9 1/2" Plaster	10 3/4" Plaster	11 7/8" Plaster	12 1/2" Gypsumboard 1/4" Plywood Paneling	13 1/2" Plywood Paneling	14 1/2" Gypsumboard 1/4" Hardboard Paneling	15 Exposed Solid Wall
Alum.Siding/1/2" Wood	A	37	35	39	40	41	37	37	38	39	41	42	37	33	39	--
7/8" Stucco/Paper	B	44	44	45	44	40	45	45	45	40	38	37	45	41	46	--
7/8" Stucco/1/2" Wood	C	45	45	45	45	42	46	46	45	42	40	39	46	42	47	--
1/2" Wood Siding	D	33	34	38	40	41	36	36	37	39	41	41	37	31	39	--
3/4" Wood Siding	E	38	37	37	38	39	34	34	35	37	39	39	35	34	37	--
4-1/2" Brick Veneer	F	53	52	52	52	48	53	53	52	48	47	46	53	50	54	--
9" Brick	G	54	57	59	58	--	58	58	59	53	53	53	53	53	53	53
4" Concrete	H	54	54	--	--	--	55	55	55	49	--	--	48	48	48	48
6" Concrete	I	54	55	57	56	--	56	56	57	50	51	51	50	50	50	50
8" Concrete	J	56	58	50	59	--	59	59	60	54	54	55	54	54	54	54
6" Hollow Concrete Block	K	46	57	49	49	--	48	48	48	42	43	43	41	41	41	41
8" Hollow Concrete Block	L	47	49	51	51	--	50	50	51	44	45	45	43	43	43	43
6" Block w/1/2" Stucco	M	47	48	50	49	--	49	49	50	43	44	44	42	42	42	41
8" Block w/1/2" Stucco	N	48	50	50	51	--	51	51	52	45	46	46	44	44	44	44

* These values are to be used in conjunction with Equation (B-12) and values for the source constant (C) of -3.5 for highway and -5.8 for aircraft noise sources.

TABLE B-2b. EWR VALUE FOR BASIC ROOF-CEILING STRUCTURES*

Single-Joist Systems					Attic Space Systems			
Roof Material	1/2" Gypsumboard	3/8" Gypsum Lath – 1/8" Plaster	1/2" Fiberboard	Open Exposed Framing		1/2" Gypsumboard	3/8" Gypsum Lath – 1/8" Plaster	1/2" Fiberboard
Wood Shingles	36	36	32	29	Wood Shingles	44	47	56
Composition Shingles	39	42	34	35	Composition Shingles	48	51	61
Clay or Concrete Tiles	47	48	41	40	Clay or Concrete Tiles	53	56	66
Built-Up Roofing	39	39	34	32	Built-Up Roofing	46	49	58
1/2" Wood – Sheet Metal	--	--	--	31	1/2" Wood – Sheet Metal	44	47	57

* These values are to be used in conjunction with Equation (B-12) and values for the source constant (C) of -3.5 for highway and -5.8 for aircraft noise sources.

TABLE B-3. ADJUSTMENTS TO BASIC EWR VALUES DUE TO MODIFICATIONS

Modification Category 1: Mass Increases	Δ EWR, dB
Double Mass One Side	3
Double Mass Both Sides	4

Modification Category 2: Stud Space Absorption	Δ EWR, dB
Absorption in Stud Space②	4

Modification Category 3: Limpness Increases	Δ EWR, dB
Fiberboard Under Both Panels	8
Resilient Mounting of One or Both Panels	8
Staggered Studs	8
24-inch Stud Spacing	2
Metal Channel Studs	5

Table Instructions

① To obtain the Total EWR adjustment for multiple modifications: add the adjustments for each of the three categories. If more than one Category 3 modification is used, count the value of the largest adjustment plus one-half of the value of the next largest.

② If fiberboard is used for a Category 3 modification, count Category 2 stud space absorption as only 2 dB.

③ An additional treatment not related to the three categories is the caulking of all tiny leaks or cracks which usually exist at exterior wall element junctions — corners, seams, etc. Sealing all such possible leaks will increase the wall EWR by 4 dB over that of standard unsealed construction. If development plans specify such complete sealing, add 4 dB to the EWR increase determined from the table.

TABLE B-4. EFFECTS OF VENTING ATTIC SPACE CONSTRUCTIONS* ON EWR VALUES WITH AND WITHOUT ABSORPTIONS

Basic Construction EWR, dB		Vented Attic EWR, dB (Without Insulation)	Vented Attic EWR, dB (With Insulation)
Plaster or Gypboard Ceiling	40 to 43	28	35
	44 to 46	29	36
	47 to 49	30	37
	50 to 52	31	38
Fiberboard Ceiling	52 to 62	39	42

* Based on minimum venting requirements of the Uniform Building Code.

TABLE B-5. ADJUSTMENT TO BASIC ROOF EWR FOR ADDITION OF INSULATION* IN NON-VENTED ATTIC/JOIST SPACES

Description	Adjustment Factor, dB (To be Added)
Single Joist Construction - All Cases	5
Attic Space Constructions -	
Fiberboard Ceiling	2
Plaster or Gyp Ceiling	6

* A minimum of 4 inches is required to count this adjustment.

TABLE B-6. EWR VALUES FOR COMMON WINDOW ASSEMBLIES*

	DESCRIPTION	EWR, dB
Single - Glazed Windows	1/16" glass	28
	1/8" glass	28
	1/4" plate glass	28
	5/16" glass	32
	3/8" glass	34
	2-ply glass, 0.53" total	42
	3-ply glass, 0.82" total	45
Jalousie Window	4-1/2" wide, 1/4" thick louvers with 1/2" overlap - cranked shut	22
Double - Glazed Windows	1/4" glass, 2" airspace, 3/16" glass	43
	3/8" glass, 2" airspace, 3/16" glass	45
	1/4" glass, 2" airspace, 3/16" glass	44
	1/8" glass, 2-1/4" airspace, 1/8" glass	36
	1/8" glass, 2-1/4" airspace, 1/4" glass	40
	1/4" glass, 2-1/4" airspace, 1/4" glass	42
	3/32" glass, 4" airspace, 3/32" glass	34
	3/16" glass, 4-3/4" airspace, 1/4" glass	48

* These values are to be used in conjunction with Equation (B-12) and values for the source constant (C) of -3.5 for highway and -5.8 for aircraft noise sources.

TABLE B-7. EWR VALUES FOR COMMONLY USED DOORS*

	DESCRIPTION	EWR, dB
Hollow Core Doors	1-3/4" wood, 1/16" undercut	20
	1-3/4" wood, Weatherstripped	21
	Steel (3.22 lbs/ft^2), Magnetic weatherstrip	32
Solid Core Doors	1-3/4" wood, 1/16" undercut	22
	1-3/4" wood, Weatherstripped	30
	1-34" wood, Drop seal threshold	39
	1-3/4" wood, weatherstripped and Aluminium storm door, glazed 1/16" glass	35
Sliding Door	Glazed 3/16" safety glass, locked	30

* These values are to be used in conjunction with Equation (B-12) and values for the source constant (C) of -3.5 for highway and -5.8 for aircraft noise sources.

REFERENCES – APPENDIX B

B-1. Sharp, B.H., Davy, B.A., and Mange, G.E., "The Assessment of Noise Attenuation Measures for External Noise", Wyle Research Report WR 76-3, Draft Report for the U.S. Department of Housing and Urban Development, April 1976.

B-2. Wyle Laboratories, "Home Soundproofing Pilot Project for the Los Angeles Department of Airports – Final Report", Wyle Research Report No. WCR 70-1, March 197

B-3. Wyle Laboratories, "Community Noise", prepared for the U.S. Environmental Protection Agency, NTID 300.3, December 1971.

B-4. Sharp, B.H., "A Study of Techniques to Increase the Sound Insulation of Building Elements, Wyle Laboratories Research Report WR 73-5, for the U.S. Department of Housing and Urban Development, June 1973.

B-5. Standard Classification for Determination of Sound Transmission Class, 1975 Annual Book of ASTM Standards, E-413-73, pp. 761-763, Part 18 (American Society for Testing and Materials, Philadelphia, 1975).

APPENDIX C

BUILDING AND ROOM CONSTRUCTION WORKSHEET

BUILDING AND ROOM CONSTRUCTION WORKSHEET

A. Name of Building ______________________________

B. Address ______________________________

____

C. Distance from Airport ______________ NEF ______________

D. Owner ______________________________

Occupancy Agency ______________________________

Person to Contact ______________ Phone ______________

E. Use: School O Hospital O Other ______________

F. Average Daily Occupancy: Staff ______________

Students/Patients ______________ Day/Night

G. Building Size: SKETCH:

No. of Stories ________

Length ________

Width ________

(Sketch layout in space to right. Show North and direction to airport.)

H. Room Size Information:

On the following table, list the nominal dimensions and numbers of rooms adjacent to outside walls. List separately for each type (i.e., use) room. If all similar-use rooms are not the same size, use a separate line for each size. Rooms with dimensions within 20% of each other may be grouped together.

	Room Use and Occupancy	Dimensions*	No. of Rooms
a.	________________	________	________
b.	________________	________	________
c.	________________	________	________
d.	________________	________	________

* Give dimension adjacent to outside wall first.

If a significant number of patient/student rooms are not adjacent to outside walls, give approximate number of building occupants using these interior rooms ______.

I. Wall Construction:

1. Outside Wall Material

O Aluminum Siding/½" Wood
O 7/8" Stucco/Paper
O ½" Wood Siding
O 3/4" Wood Siding
O 4-½" Brick Veneer
O 9" Brick
O Other ____________
O 6" Concrete
O 8" Concrete
O 6" Hollow Concrete Block
O 8" Hollow Concrete Block
O 6" Block w/½" Stucco
O 8" Block w/½" Stucco

2. Interior Finish Material of Exterior Walls

O ½" Gypsumboard
O 3/8" Gypsumboard
O 2 Layers ½" Gypsumboard
O 2 Layers 5/8" Gypsumboard
O 3/8" Gyp. Lath/ 1/8" Plaster
O ½" Plaster
O 3/4" Plaster
O 7/8" Plaster
O ½" Gyp./¼" plywood paneling
O ½" Plywood Paneling

Interior Finish Material of Exterior Walls (Continued)

O $\frac{1}{2}$" Soundboard/$\frac{1}{2}$" Gyp.   O Exposed Exterior Wall

O $\frac{1}{2}$" Soundboard/3/8" Gyp.   O Plywood Paneling

O Other ____________________

3. Stud Arrangements in Exterior Walls

O No studs

O 2" x 4" studs, 16" spacing

O Other studs. Size ______________ Spacing ______________

O Staggered studs

O Metal channel studs

4. Insulation in Stud Space

Type ________________

Thickness ____________

5. Special Features

O Resilient mounting of panels

O Fiberboard under panels   O one side   O both sides

O Double layer panels   O continuously glued   O spot laminated

J. Roof and Ceiling Construction

(If utilization of top story is not similar to other floors, please note difference under "additional comments".)

1. O Single joist construction or O Attic Space Construction

2. Roof Construction

O Concrete slab. Thickness ______________

O Wood. Type ______________ Thickness ______________

O Metal deck. Thickness ______________

Rafter spacing ________________

Joist Spacing (if attic space construction) ______________

3. Exterior Material

   O Wood Shingles
   O Built-up Roofing. No. Plies ____
   O Composition Shingles
   O Clay or Concrete Tiles
   O Other ______________________

4. Ceiling Material

   O ½" Gypsumboard
   O ½" Fiberboard
   O 3/8" Gyp. Lath/ 1/8" Plaster
   O Exposed Framing
   O Other ______________________

5. Insulation

   Type ____________________ Thickness ____________________

6. If attic space, O Vented or O Unvented

K. Windows*

The following information is needed for each room type listed under H. If windows differ for similar type rooms, indicate the breakdown.

1. Number of windows per room ____________
2. Window size ____________
3. Thickness of glass ____________
4. If laminated glass, number of plies ____________
5. If double glazed, thickness of air space ____________
6. If jalousie, width of slats ________ and overlap when closed ________
7. If normally open, fraction of window area which is open ____________
8. Do windows open? O or are they non-operable? O
9. Type of frame and seals ______________________________

* Including sliding glass doors.

L. Exterior Doors*

O Solid Wood

O Hollow Core O Wood O Steel

Type of seal: O Gap at bottom

O Weather stripped

O Other type seal ______________________

O Storm door also

* Only if a substantial number of rooms have exterior doors. Consider sliding glass doors to be windows.

M. Ventilation System

O Windows only O Central forced air

O Through-the-wall air conditioners

Number per room ______________

Dimensions of opening ______________

N. Room Interior*

The following is needed for each room type listed under H.

1. Percent of floor carpeted ______________

2. Percent of wall covered with heavy drapes ______________

3. Acoustical tile on ceiling? O Yes O No

4. Number of doors leading to interior rooms or hallways ______________
   (Describe unusually large doors below.)

* Please provide breakdown if not typical for all.

O. Additional Comments ____

____

____

Additional Comments (Continued)

Prepared by

Date

O Supplemental sheets attached

APPENDIX D

COMPILATION OF BUILDING INVESTIGATIONS

TABLE D-1

SUMMARY OF BUILDING INVESTIGATION

Airport Los Angeles International City LAX State California

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Interior	Roof	Ceiling	Windows: Size	No.	Ventilation	No. of Floors	Rooms*: Size	No.	Student/ Patient No.
1. Imperial Sch.	540 Imperial Ave.	30	0.5	1953	9"Brick	1/2" Gypsum 1/2" Plywood	Wood	1/2"Fiberboard Acoustic Tile	3'5"x 4'10"	60% Ext. Wall	Central Forced Air	1	900'^{2}	14	60
2. Clyde Woodworth Sch.	3200 W 104th Str.	30	2.3	1954	1"Wood and Stucco	1/2"Gypsum	1"Wood 6 Ply + Slag	Acoustic Tile	3.5'x 8'	6	Windows Only	1	34'x28'	32	1,035
3. Lennox High Sch.	11033 Buford Ave.	30	0.1	1957	6"Concrete and Stucco	1/2"Gypsum-board	1"Wood 6 Ply + Slag	Acoustic Tile	42"x 60"	50%	Windows Only	1	31'x28'	36	1,228
4. Felton Avenue Sch.	1041 Felton Ave.	30	0.2	1950	1"Wood Siding + Stucco	1/2"Gypsum 1/2" Plaster 1/2" Plywood	1"Wood Planks	1/2"Acoustic Tile	3'x9'	6	Windows Only	1	30'x30'	20	700
5. Figueroa Street Sch.	510 W 111th Str.	30 out	4.8	1950	9"Brick + Stucco	3/4"Plaster + 1/2"Scratch Wood Lath	1"Wood Planks, 6 Ply +Slag	Plaster	3'x8'	5	Windows Only	2	30'x30'	12	
ALT 98th Street Sch.	5431 W 98th Str.	30	0.2	1958	3/4 Wood Siding + Stucco	1/2" Gypsum	1"Wood Planks, 6 Ply + Slag	1/2"Acoustic Tile	3'x8'	5	Windows Only	1	30'x30'	14	
6. Westchester High Sch	7400 W. Manchester	30	0.5	1958	8"Reinforced Concrete	1/2"Gypsum 1/2" Plaster	6"Concrete		3'x8'		Windows Only	1	30'x25'	58	2,500
7. Imperial Hospital	11222 Inglewood Ave.	30	0.5		8"Concrete 8"Brick	1/2"Gypsum 1/2"Plaster	6"Concrete		6'x6'		Windows Only	2	16'x12'	92	92
8. Inglewood Hospital	426 E 99th Str.	30	1.0	Before 1958	3/4 Wood + Stucco	1/2"Gypsum 1/2" Plaster	1"Wood Plank, 6 Ply Slag		8'x8'		Window + Forced Air	1	14'x18'	28	28
ALT. Lawndale High Sch.	14901 Inglewood Ave.	30 out	2.4		8" Concrete 8" Hollow Concrete Block	Painted Concrete Block	6" Slab Reinforced Concrete		3'x6'		Windows Only	2	25'	50	2,000
9. Morningside Sch.		37	2.0		9" Brick	3/8 Gypsum	Wood		1/2 Gypsum 1 1/4 x 3'7"		Windows Only	1	34' x 28'	72	17[illegible]
10. Centinela Hospital		30	1.8		8" Concrete	1/2 plaster	Concrete Slab		3'7" x 4'3"		Windows Only	8	15' x 15'	260	[illegible]70

*Include patient beds.

TABLE D-2

SUMMARY OF BUILDING INVESTIGATION

Airport Stapleton City Denver State Colorado

Name of Building	Location	NEF	Miles from Airport	Year Built	Exterior	Interior	Roof	Ceiling	Size	No.	Ventilation	No. of Floors	Size	No.	Student/ Patient No.
1. Clyde Miller Elem. Sch.	2300 Tower Rd. Aurora			1953	8"Concrete Block w/ Brick Ext.	Exposed Ext. Wall Painted	1"Wood Sheathing Shingles	Hard Plaster	4'x 7'	7		1	30'x 20'	5	125
2. Denver General Hosp.	West 8th & Cherokee	out 30	6.0	1967	5"Precast Concrete, 2" rigid firm insulation ½" Gypsumboard	½" Gypsum	3" Concrete Slab	½"Gypsumboard	5'x various	5	Central Forced Air	8	26'x 21'	100	350
3. Parklane School	13001 E. 30 Ave. Aurora	30	1.2	1954	4"Brick on 8" Concrete Block	Exposed Ext. Wall	Metal Deck	3/4"Acoustic Plaster on Metal Lath	4'x 6'8"	6	Unit Ventitors	1	27'5"x 31'	23	495
4. Sable School	2601 Sable Blvd.	30	2.0	1962	9"Brick - 4" Brick w/ 8" Block	Exposed Concrete Block	Acoustic Plaster				Windows Only	1	22'6"x 19'6"	26	840
5. Montview School	2055 Moline		0.6	1951	7/8"Stucco/ Paper and 4" Brick w/ 8" Block Backup	3/4" Plaster	3/4" Wood	Acoustic Plaster on Metal Lath	3'10"x 2'9"	10	2 through the wall air-conditioners per room	1	36'x 22'	23	25C
6. North Junior High Sch.	12095 Montview Blvd.	30	0.8	1957	12" Masonry Wall w/ Brick Exterior	Structural Glazed Tile	2"Gypsum Deck on 1" Formboard on Steel Joists	Acoustic Plaster on Suspended Metal Lath	4'x 2'	5	Windows & Unit Vent		30'x 24'	25	1,000
7. Elyria Sch.	4725 High Str.	out 30	3.7		13"Masonry Wall w/ Brick Exterior	3/4" Plaster	1"Wood Sheathing	3/4" Plaster on Metal Lath w/ Applied Acoustical Tile	3'8"x 7'	5	Windows& Unit Vent Heaters	1	30'x 22'2"	4	78

TABLE D-2 (Cont'd.)

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Interior	Roof	Ceiling	Windows: Size	No.	Ventilation	No. of Floors	Room: Size	No.	Student/ Patient No.
8. Smiley Jr. High Sch.	2540 Holly North Hill Park	30	1. 2	1928	1'8"Walls Terra Cotta Exterior Keene Cement & Plaster	Keene Cement Plaster	2 1/2" Concrete Slab	Acoustic Plaster	9'x 5'	5	Window and Unit Venti-lation	3	34'8" x 32'	45	1,425
9. Paris Sch.	1635 Paris Str.	30	1. 1	1956	12"Wall-Face Brick Exterior and Interior	Face Brick	Skylight	Acoustic Plaster	3'9 3/4" x 7'8"	7	Windows & Unit Venti-lators	1	31'4"x 32'	8	270
10. Fitzsimons Army Hosp.	Peoria & Montview Blvd.	30	0. 4	N. A.	13" Face Brick	3/4" Plaster	3"Con-crete Slab	Hard Plaster	2'8"x 5'5"	1	Windows	4	8'6"x 14'6"	610	937
11. Hallett Sch.	2950 Jasmine	30	1. 1		1"Concrete Block	Concrete Block	2 1/2" Concrete Slab	Acoustic Tile Applied to Concrete Slab(1st Floor) or to Suspended Plaster Ceiling (2nd Floor)	6'9"x 4'8"	8	Windows 8"x54" Unit Vent	2	32'x 24'	26	500
12. Boston Sch.	1365 Boston Str.	30	1. 1		12"Wall-4" Face Brick Interior and Ex-terior	1/2" Plaster Face Brick	Skylight	Acoustic Plaster	3'9 3/4" x 7'8"		Windows & Inlet Vents	1	31'4"x 32'		150

TABLE D-3

SUMMARY OF BUILDING INVESTIGATION

Airport Sky Harbor City Phoenix State Arizona

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Interior	Roof	Ceiling	Windows: Size	No.	Ventilation	No. of Floors	Room: Size	No.	Student/ Patient No.
1. Grant Elem. Sch.	720 S 4th Str.	30	2.8	1929	Brick	3/4" Plaster	Asphalt Shingles	Metal Lath Plaster	3'10"x 7'3 7/8"	5	Central Forced Air	1	31'x25'	22	442
2. Adeline Gray Sch.	201 E. Durango	30	2.3	1950	12"Brick	3/4" Plaster	1"Wood Sheath-ing	Acoustic Tile	7'5"x 3'8"	6	Windows Only	1	32'x24'	7	201
3. Lincoln Ab. Elem. Sch.	1021 E. Buckeye Rd.	30	2.0	1946	9"Brick	5/8" Plaster on Brick	1"Wood Sheath-ing, Shingles	3/4"Plaster on Metal Lath acoustical tile	3'8 7/8" x 2'1"		Windows Only	1	24'x37'	12	300
4. Dunbar Elementary Sch.	701 S. 9th Ave.	30	3.0	1925	1'3" Brick	3/4" Plaster	7/8"Wood Sheathing	3/4"Plaster on Metal Lath	3'9"x 7'2"		Windows Only	1	31'5"x 24'6 1/2"	17	425
5. Herrera Silvestre Elem. Sch.	1450 S. 11th Str.	30	2.0	1956	4"Brick w/ Concrete Block	Exposed Ext. Wall	Comp. Shingles	Acoustic Tile Applied To Plaster	8'2"x 6'5 1/2"	5	Central Forced Air	1	26'8"x 32'	8	120
6. Ann Ott Sch.	12th Str. & Apache Str.	30	1.75	1946	Plaster on Brick		Wood Sheathing	Acoustic Tile	4'x8'1"	6		1	30'x24'	21	588
7. Skiff Elem. Sch.	1430 S. 18th Str.	30	0.8	1958	12" Concrete Block	5/8" Plaster	1"Wood Sheathing	Acoustic Tile	3'8 7/8" x 6'9"	7	Forced Central Air Evaporative Air	2	35'3"x 25'	35	800
8. Wilson Hawkins Elem. Sch.	2411 E. Buckeye Rd.	30		1958	Brick	5/8" Plaster	1"Wood Sheathing	Acoustic Tile	6'9"x 3'8 7/8"	7	Forced Central Air Evap. Coolers	2	35'3"x 25'	21	1,000
9. Arizona St. Hosp.	2500 E. Van Buren	30	3.1	1970	10" Brick Reinforced	Exposed Ext. Wall	10"Pre-Cast Slab		5'x8'	2	Central Forced Air	1	9'6"x 13'4"	72	662
10. Children Hosp.	200 N. Cury	30	3.1	1962	4"Brick Con. Block Cement Grout	5/8" Plaster	3"Con-crete Slab	Plaster	4'x 5'5 3/4"	2	Central Forced Air	3	12'x 15'10 3/4"	70	150

TABLE D-4

SUMMARY OF BUILDING INVESTIGATION

Airport Logan City Boston State Massachusetts

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Interior	Roof	Ceiling	Windows: Size	No.	Ventilation	No. of Floors	Room: Size	No.	Student/ Patient No.
1. Winthrop Comm. Hosp.	44 Lincoln Str. Winthrop	30	0.4	1930	9"Brick	1/2" Gypsum	6"Con- crete Slab	1/2"Gypsum- board	35"x 71"	2	Windows Only	3	11'10"x 20'2"	54	235
2. Winthrop Jr. High Sch.	44 Lincoln Str. Winthrop	30	0.5	1968	9"Brick, 9" Concrete Block	Exposed Con- crete Block	6" Con- crete Slab	1/2"Gypsum- board	8'5"x 4'	2	Windows, Heat Vent System	2	31'1"x 23'9"	45	919
3. Julia Ward Howe Sch.	Crescent Ave. Revere	30	1.3	1890	3/4" Wood Siding	3/8" Gypsum Lath, 1/8" Plaster	3/4"Wood Shingles	3/8" Gypsum Lath, 1/8" Plaster	48"x 8'	6	Windows Only	2	28'x30'	10	210
4. Garfield Jr. High Sch.	Revere	30	1.7	1927	14"Brick Wood Lath & Plaster	3/8" Gypsum Lath W/ 1/8" Plaster	1"Wood Plank	3/8"Gypsum Lath, 1/8" Plaster	46"x 94"	6	Windows Only	3	24'5"x 30'	27	400
5. Cheverus Sch.	10 Moore St. E. Boston	30	0.6	1908	18"Brick & Concrete Column	3/8"Gypsum & Wood Lath w/ Plaster	6"Con- crete Slab, 6 Ply+Slag	Exposed Con- crete, Ceiling Painted	45'x 8'8"	4	Windows Only	3	22'8"	18	315
6. Chapman Sch.	61 Eataw E. Boston	30	1.0	1900	16"Brick & 3/4" Plaster	3/8"Gypsum Lath 1/8" Plas- ter on Back Bearing Wall	16"Block w/ 3/4" Plaster	3/4" Wood Plank-6 Plys + Slag	8'8"x 4'0"	7	Windows Only	3	27'3"x 31'6"	18	129
7. Chelsea Mem. Hosp.	Chelsea	30	1.3	1909	8"Brick & 4" Block w/ rein- forced Concrete Frame	Painted Cement Block	6" Con- crete Slab 6 Ply + Slag	1/2" Gypsum & Acoustic Tile	27"x 48"	2	Windows Only	3	11'8"x 16'	28	75
8. Williams Sch.	5th & Arlington Str. Chelsea	30	1.6	1909	16"Brick w/ Plaster & Wood Lath	3/8" Gypsum Lath & 1/8" Plaster	3/4" Wood Plank 6 Ply + Slag	3/8"Gypsum Lath & 1/8" Plaster	52"x 8'	4	Windows Only	3	32'9"x 27'3"	75	1,400

TABLE D-4 (Cont'd.)

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Interior	Roof	Ceiling	Windows: Size	No.	Ventilation	No. of Floors	Room: Size	No.	Student/ Patient No.
9. Edward School	Main Street Charlestown	out 30	2.5	1931	12" Brick & Plaster Coat	3/4" Plaster on 12" Brick Wall	3/4" Wood Sheathing 6 Ply+Slag	3/8"Gypsum Lath & 1/8" Plaster	54"x 108"	4	Windows Only	3	22'6"x 29'8"	20	530
10. Barnes Elem. Sch.	127 Marion Str. E. Boston	30	1.0	1898	18"Brick	3/4" Plaster + 1/8" Finish	1"Wood Plank, 6 Ply+Slag		62"x 52"	3	Windows Only	3	27'6"x 33'3"	52	796
11. Shurtleff Sch.	Central Ave. & Shurtleff Str. Chelsea	30	1.3	1911	9"Brick	3/8"Gypsum Lath & 1/8" Plaster	6"Concrete Slab 6 Ply + Slag			1		3	28'x30'		1,600
12. Lawrence Mem. Hosp.	193 and Governors Ave.	out 30	5.8	1922-1976	9"Brick & Plaster Walls	3/8"Gypsum Lath & 1/8" Plaster	6" Concrete Slab 6 Ply + Slag	3/8" Gypsum Lath & 1/8" Plaster	6'x 8'	1	Windows Forced Air Cool Water	1-6	14'x16'	100	200

TABLE D-5

SUMMARY OF BUILDING INVESTIGATION

Airport Miami International City Miami State Florida

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Construction Materials: Interior	Construction Materials: Roof	Construction Materials: Ceiling	Window: Size	Window: No.	Ventilation	No. of Floors	Room: Size	Room: No.	Student/ Patient
1. Dunbar Elementary School	505 N. W. 20th Str.	30	4.0		8"Block with 1/2"Stucco	Concrete Block and Stucco	6" Concrete Slab	1/2"Acoustic Ceiling	2'x7'	12	Central Forced Air	2	28'x35'	34	628
2. Jackson Memorial Hospital	1611 N. W. 12th Ave.	30	3.5		8"Concrete Block	1/2"Plaster wire mesh 6" Hollow Block	6"Concrete Slab	1/2"Acoustic Tile	2'x5'	2	Windows Central Forced Air	14	12'x22'	735	1,250
3. Pan American Hosp.	5959N. W. 7thStreet	30	0.6		8"Hollow Concrete and Block +Stucco	1/2"Plaster on Concrete Blocks	6"Concrete Slab	1/2" Acoustic Tile	2 1/2' x 5'	3	Windows-Through-the Wall Air Cond. C. F. A. Units	2	12'x16'	88	118
4. Citrus Grove Elem. Sch.	2121 N. W. 5th Str.	30	2.8		8"Block and 1/2"Stucco Brick Veneer	1/2"Acoustic Tile on Blocks	4"Concrete Slab 6 Ply+	1/2"Acoustic Tile	3'x5'	14	Windows Only	1	32'x45'		990
5. Wheatley Elem. Sch.	1801 N. W. I Place	30	4.4		8"Block + 1/2" Stucco Brick Veneer	Painted Block	6"Concrete Slab, 6 Ply + Slag	1/2" Acoustic Tile	2 1/2' x 7'	7	Windows Only	1-2	28'x30'	34	551
6. Booker T. Washington School	1200 N. W. 6th Str.	30	4.2		8"Hollow Concrete Block + Stucco	1/2"Plaster	6"Concrete Slab, 6 Ply +Slag	1/2"Acoustic Tile	3'x7'	11	Windows Only	3	25'x45'	54	862
7. Auburndale Elementary School	3255 S. W. 6th Str.	30	2.1	1949	8"Block with 1/2"Stucco 8"Adobe Brick	1/2"Plaster	1"Wood Plank 6Ply+Slag	1/2"Acoustic Tile	3 1/2'x 8'	6	Windows Only, Some Window Air-Conditioners	2	28'x30'	60	776

TABLE D-5 (Cont'd)

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Interior	Roof	Ceiling	Windows: Size	No.	Ventilation	No. of Floors	Room: Size	No.	Student/ Patient
8. Kensington Elem. School	711 N. W. 30th Str.	30	2.0	1950	8"Block with 1/2" Stucco	Painted Block	6"Con-crete Slab	1/2"Acous-tic Tile	3 1/2"x 7"	7	Central Forced Air	1	26'x30'	43	988
9. Buena Vista Elem. School	3001 N. W. 2nd Ave.	30	4.3		8"Block and 1/2" Stucco	1/2" Plaster	6"Con-crete Slab, 6 Ply +Slag	3/8"Gyp. Lath and 1/8"Plaster	4'x8'	5	Windows Only	2	25'x30'	22	349
10. Robert Lee Jr. High School	3100 N. W. 5th Ave.	30	4.0	1924	8"Block and 1/2"Stucco	Painted Blockq	6"Con-crete Slab, 6 Ply +Slag	Exposed Concrete Beam	4'x8'	5	Window and Window Air-Conditioner	3	26'x30'	30	825

TABLE D-6

SUMMARY OF BUILDING INVESTIGATION

Airport Wm. Hartsfield City Atlanta State Georgia

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Construction Materials: Interior	Construction Materials: Roof	Construction Materials: Ceiling	Windows: Size	Windows: No.	Ventilation	No. of Floors	Room: Size	Room: No.	Student/Patient
1. Newton Estates Sch.	3950 Northwest Dr. College Park	30	1.2	1952	4"Brick 8"Concrete Block	Concrete Block	7½" Concrete Slab	Acoustic Tile	10'9"x 8'1"	3	Windows Only	2	36x25	6	192
2. Longino School	2001 Walker Ave. College Park	30	1.3	1952	4"Brick on Concrete Block	Concrete Block	2" Concrete Slab	Acoustic Tile	5'x6'	6	Windows Only	2	36'x23	13	259
3. Lake Shore High School	2134 Lake Shore Ave. College Park	30	2.5	1965	4"Brick 8"Block	Painted Concrete Block	2½" Concrete Slab	Acoustic Tile	14'4"x 7'1"	2	Windows Only	2	30'x22	45	927
4. Eastern School	Campbell Road	30	2.8	1957	4"Brick 8"Concrete Block	Exposed Concrete Block	2"Concrete Slab	Acoustic Tile	8'6"x 8'	3	Windows Only	2	36'x 23"	8	214
5. College Park High School	3605 Maine College Park	30	0.9	1940	10"Concrete	½" Plaster	2"Concrete Slab 2"Insulation	Metal Lath ¾" Plaster	11'4"x 8'6¾"		Windows Only	2	22'x 30'	25	477
6. Woodward Academy	1130 Spaulding Drive, N. E., Atlanta	30	0.7		8"Brick 4" Concrete Block	½"Plaster	6"Slab 6 Ply + Slag	½"Plaster	6'x5' & 3'x5'	3	Windows Only	3	16'x 46'	26	1,650
7. Fountain School	2071 Boulevard Dr. Atlanta	30	2.9		8"Brick	6"Concrete Block Plus Painted Walls	6"Concrete Slab, 6 Ply + Slag	½" Acoustic Tile	4'x5'	6	Windows Only	1	26'x 30'	16	406
8. Crawford Long Sch	3200 Lafona Dr., S.W.	30	1.7		8"Brick	6"Hollow Concrete Block + Paint	6"Concrete Slab	½" Acoustic Tile	3'9" X6'	10	Windows Only	2	28'x 36'	42	925
9. George High Sch	800 Hutchense Rd.	30	3.0	1972	8"Brick	6"Hollow Block Wall and Paint	8"Concrete Slab 6 Plys + Slag	½"Acoustic Tile	6'5"x 4'	8	Central Forced Air	3	140'x	30	1,046

TABLE D-6 (Cont'd.)

Name of Building	Location	NEF	Miles from Airport	Year Built	Construction Materials: Exterior	Construction Materials: Interior	Construction Materials: Roof	Construction Materials: Ceiling	Windows: Size	Windows: No.	Ventilation	No. of Floors	Room: Size	Room: No.	Student/Patient
10. Samuel R. Young School	710 Temple Avenue College Park	30	0.3	1952	4"Brick and Concrete Block	Exposed Concrete Block	2"Gyp- sum deck 5 Ply	Acoustic Tile	8'1"x 4'	2	Windows Only	1	31'10"x 24'10¼"	22	363
11. St. John School	240 Arnold Street Hapeville, Georgia	30	3.4		8"Brick	6"Hollow Con- crete Block	6"Slab	½" Acoustic Tile	4'x6'	8	Windows Only	1	24'x36'	10	

TABLE D-7

OVERALL ROOMS AND WINDOWS

Summary of Numbers and Sizes				
	Average No. of Rooms	Average Room Size	Average No. of Windows	Average Window Size
All Schools	23.56	32'9"x29'2" ($955.02ft^2$)	5.38	4'4 1/2"x6'4" ($27.86ft^2$)
All Hospitals	179.7	12'5"x17'10 1/2" ($222.5ft^2$)	1.98	2'11"x5'4" ($15.51ft^2$)

TABLE D-8

HOSPITAL WINDOWS AND ROOMS

Summary of Numbers and Sizes				
City	Room Number	Room Size	Window Number	Window Size
Atlanta (E)				
Miami (C)	411.5	12' x 21'4"	2.43	2'1" x 5'
Phoenix (B)	71	10'9" x 14'6"	2.21	4'5" x 6'8"
Boston (D)	60.6	13' x 17'3"	1.45	3'11" x 6'3½"
Denver (F)	355	12'8" x 15'5"	1.56	3'9" x 5'5"
Los Angeles (A)	60	15'6" x 13'5"		

TABLE D-9

SCHOOL ROOMS AND WINDOWS

Summary of Numbers and Sizes				
City	Room Number	Room Size	Window Number	Window Size
Atlanta (E)	22	40'3" x 30'2"	4.8	5'8" x 5'6"
Miami (C)	39.5	32'8" x 33'6"	7.8	3' x 7'3"
Phoenix (B)	17.8	31'9" x 26'2"	4.9	4'11" x 6'3"
Boston (D)	30.8	29' x 28'1"	3.9	5'2" x 6'10"
Denver (F)	11.7	28'11" x 24'5"	9.8	5'2" x 4'3½"
Los Angeles (A)	23.25	30'11" x 27'8"	2.3	3'3" x 8'

APPENDIX E

CALCULATED NOISE REDUCTIONS

TABLE E-1. CALCULATED NOISE REDUCTIONS — LAX

Building	Room	$S \cdot 10^{-EWR/10}$ (ft^2) Windows	Doors	Walls	Roof	A (sabins)	NR (dB)
Imperial School	2, 11	.1846	.0317	.0036	.0014	1250	26
	6	---	.0317	.0108	.0014	1000	32
Lennox H.S.	4Bldg3, 3Bldg6, 3 Bldg 4	.167	.126	.0043	.0014	630	21
Felton Ave. School	9, 5, 11	.428	.013	.020	.0451	630	19
Clyde Woodworth School	4	.3772	.1912	.0826	.0015	630	18
Morningside H.S.	J2	.3675	.1207	.004	nil	500	18
	V2	.1647	.1207	.004	nil	500	20
Centinella Hosp.	5114, 8128	.0225	---	nil	---	125	26
Westchester H.S.	F9	.3899	---	.0024	.0075	500	19
Imperial Hospital	227, 224	.036	---	.0003	---	140	24
Figueroa St. School	Classroom	.1902	---	.001	.0113	500	22
Lawndale H.S.	Lower Story	.114	.110	nil	---	630	23
	Upper Story	.224	---	nil	.009	630	23

TABLE E-2. CALCULATED NOISE REDUCTIONS — PHX

Building	Room	$S \cdot 10^{-EWR/10}$ (ft^2)				A (sabins)	NR (dB)
		Windows	Doors	Walls	Roof		
Grant Elem. School	Classroom	.2219	---	.0012	.0616	800	22
Adeline Gray School	6	.2615	.0798	.0005	.0122	800	22
Lincoln Elem. School	Classroom	.2853	.0798	.0043	.3535	1000	20
Skiff Elem. School	2nd Floor Classroom	.2853	.1262	.0126	.0220	800	21
Wilson Hawkins Elem. School	2nd Floor Classroom	.2853	.1262	.0020	.0220	800	21
Dunbar Elem. School	Classroom	.2140	---	.0019	.0613	630	22
Silvestre Herrera Elem. School	2	.2457	---	.0017	.4330	800	19
Ann Ott (Stevenson) School	Classroom	.3075	.0798	.0010	.0361	630	20
Arizona State Hosp.	Patient Room	.0106	.1262	.0005	nil	125	18
Arizona Children's Hospital	Patient Room	.0998	nil	.0003	.0001	125	19

TABLE E-3. CALCULATED NOISE REDUCTIONS — MIA

Building	Room	$S \cdot 10^{-EWR/10}$ (ft^2)							
		Windows	Doors	Walls	Roof	A/C Units	Vents	A (sabins)	NR (dB)
Dunbar Elem. School	Classroom	.0168	.0200	.0204	.0016	---	---	800	29
Jackson Memorial Hospital	Patient Room	.0317	---	.0005	.0026	---	---	250	27
Citrus Grove Elem. School	Classroom	1.325	.2524	.0262	.0321	---	---	1600	18
Wheatly Elem. School	Classroom	.1981	.1262	.0036	.0084	---	---	800	22
Booker T. Washington School	3rd Story Classroom	.3661	---	.0070	.0113	---	---	800	21
Pan American Hosp.	Patient Room	.0594	---	.0025	.0019	.0190	---	200	22
Auburndale Elem. School	Classroom	.2663	.2524	.0022	.3344	.0190	2.389	630	11
Kensington Elem. School	Classroom	.2718	.0200	.0171	.0078	---	3.344	630	11
Buena Vista Elem. School	Classroom	.2536	---	.0044	.0008	---	---	630	22
Robert E. Lee JHS	Top Story Classroom	.2536	.0252	.0056	.0078	.0285	.0107	630	21

TABLE E-4. CALCULATED NOISE REDUCTIONS — BOS

		$S \cdot 10^{-EWR/10}$ (ft^2)						
Building	Room	Windows	Doors	Walls	Roof	Skylight	A (sabins)	NR (dB)
Winthrop Community Hospital	319	.1712	---	.0012	---	---	430	22
	271	.0250	---	.0012	---	---	250	28
Winthrop JHS	206	.0457	---	.0014	nil	---	500	28
	220	.1412	---	.0043	nil	---	700	25
Julia Ward Howe School	1st Floor Classroom	.2536	---	.0368	---	---	630	22
	2nd Floor Classroom	.2536	---	.0368	.421	---	630	18
Garfield JHS	Classroom	.2855	---	nil	nil	---	630	22
Cheverus School	8, 2	.2068	.1262	nil	nil	---	500	20
Chapman School	Top Floor Classroom	.3861	---	nil	.4939	---	350	14
	Lower Floor Classroom	.3861	---	nil	---	---	350	18
Chelsea Memorial Hospital	201, 210	.0285	---	nil	nil	---	200	27
Williams School	Top Floor Classroom	.2198	---	.0008	.0112	---	500	21
Edward School	Classroom	.2568	---	nil	nil	---	370	20
Barnes School	Top Floor Classroom	.1065	---	nil	nil	.1268	630	21
Lawrence Memorial Hospital	435	.0761	---	nil	nil	---	160	21
	206	Construction Data Not Provided					520	--

TABLE E-5. CALCULATED NOISE REDUCTIONS — ATL

Building	Room	$S \cdot 10^{-EWR/10}$ (ft^2) Windows	Walls	Roof	A (sabins)	NR (dB)
Newton Estates School	Classroom	.4184	.0068	.0036	800	21
Longino School	Classroom	.2853	.0018	.0131	800	22
Lake Shore H.S.	Classroom	.333	.001	.001	800	22
Eastern School	Classroom	.3804	.0012	.0131	800	21
College Park H.S.	Classroom	.3089	.0009	.0021	630	21
Woodward Academy	Classroom	.0951	.0019	.0015	1250	29
William A. Fountain School	Classroom	.1902	.0007	.0012	800	24
Crawford Long School	Classroom	.3566	.0007	.0016	800	22
Samuel Young School	Classroom	.4057	.0008	.0013	800	21
St. John School	Classroom	.3804	.0016	.0012	1250	23

TABLE E-6. CALCULATED NOISE REDUCTIONS — DEN

Building	Room	$S \cdot 10^{-EWR/10}$ (ft^2) Windows	Doors	Walls	Roof	Unit Vent	Glass Blocks	A (sabins)	NR (dB)
Clyde Miller Elem. School	Classroom	.3106	---	.0052	.0755	---	---	400	18
Park Lane Elem. School	20, 6	.2549	---	.0043	.0085	.0095	---	800	23
Sable School	Faculty Dining Room	.3423	.0317	.0010	.0024	---	---	250	16
	4	.3059	.0340	.0010	.0024	---	---	1000	23
Montview School	Classroom	.1173	.1589	.0366	.0315	.0197	---	630	21
North JHS	12	.1141	---	.0003	.0720	.0126	---	630	24
	13	.3360	---	.0003	.0720	.0126	---	630	21
Fitzsimons Hospital	4133, 4062	.0235	---	.0007	---	---	---	160	26
Boston Elem. School	1	.3426	---	.0006	.0101	.0142	.0064	800	21
Paris Elem. School	1	.3426	---	.0006	.0101	.0142	.0064	800	21
Denver General Hospital	Patient Room 13' x 15'	.1030	---	.0002	---	---	---	150	20
Elyria School	Classroom	.2052	---	.0039	.2628	.0095	---	500	18

APPENDIX F

INSTRUMENTATION

Tape Recorder:	Kudelski Nagra IV-SJ
Tape:	3M Low Noise 18-7
Tape Speed:	3-3/4 inches per second
Microphone:	Bruel & Kjaer $\frac{1}{2}$" Condenser Microphones Type 4133 Type: Free-field 0° linear response *Temperature Coefficient:* Less than ± 0.1 dB/°C between -50°C and +60°C Ambient Pressure Coefficient: -0.1 dB for +10% pressure change Relative Humidity Influence: Less than 0.1 dB
Preamplifiers:	Kudelski
Sound Level Meter:	Bruel & Kjaer Precision Sound Level Meter Type 2203, ANSI Type I Equipped with Octave Filter Set Type 1613 (In Boston, the SLM, equipped with Flexible Extension Rod UA 1096, was used as an amplifier for the interior recorded channel.)
Field Calibrator:	Bruel & Kjaer Type 4230 Calibration Level: 94 dB Frequency: 1000 Hz $\pm$ 1.5% Accuracy: $\pm$ 0.25 dB @ 25°C $\pm$ 0.50 dB between 0°C and 50°C Ambient Pressure Influence: $\pm$ 0.05 dB /100 mbar from 500 to 1100 mbar Temperature Coefficient: See Accuracy

APPENDIX G

COMPARISON OF MEASURED AND PREDICTED NOISE REDUCTION

G-1 Measured Noise Reduction

Tables G-1 through G-3 show the measured exterior noise levels (corrected to free-field), interior noise levels, and noise reduction. Except where noted otherwise, each value shown is the average of measurements from twelve aircraft noise events. The standard deviation for each set is shown. In addition to measurement variations, the standard deviation of the levels represents the variation of levels between aircraft. The standard deviation of the noise reductions is due to variations in NR associated with aircraft spectrum variations, plus spatial variations in noise within the room. These variations are normally expected, and are the reason why NR is taken as the average of a number of events and a number of interior positions.

G-2 Comparison With Prediction

Tables G-4 through G-6 show the measured and predicted NR for each room, together with the difference (Δ). The difference is the predicted value minus the measured value.

A statistical analysis of the differences has been performed for the buildings around each airport, and is summarized in Table G-7. Shown are the mean difference, standard deviation of differences, and 90 percent confidence limits.

The confidence limits are illustrated in Figure G-1. Shown are the 90 percent confidence limits for the three city groupings, relative to $\Delta = 0$. Also shown for comparison is the computed confidence limit of ± 1.9 dB given in Table B-1 of Appendix B for the difference between noise reductions computed with EWR and by the classical method using transmission loss data at each frequency band. While the confidence limits about the mean for each city fall well within this expected EWR confidence interval, the extremes of the confidence limits for the measured data for all three cities extends to ± 2.5. However, considering inherent field measurement accuracy of typically ± 1-2 dB, these confidence limits for the difference between measured and predicted noise reduction are quite reasonable. The use of the EWR method for the present project is thus validated.

G-3 Comparison of Aircraft Noise Levels With Predictions

At each measurement location predicted noise levels were obtained from the fleet median noise contours discussed in Chapter 3. Figure G-2 shows the statistical distribution of the differences between predicted levels and levels recorded at each study building. Predicted is subtracted from measured, so that a positive difference means a louder measured event. The curves shown are the cumulative distributions, and represent the percentage of events which exceed the difference shown on the abscissa.

The following points may be noted on Figure G-2:

- The standard deviation is approximately 8 dB. This is a typical variation observed between aircraft levels at a given point.

- The predicted levels are somewhat higher than median. This may be due to quieter aircraft types (general aviation jets, non-jet aircraft) being in the measured sample. Aircraft were not identified during measurements; in some cases they could not even be seen.

- Predicted levels corresponded to the 40th noisiest percentile of measurements at DEN, 20th at LAX, and 10th at BOS.

The difference in mean between the three airports shows that no one noise contour can be applied equally well to all airports. The one used did, however, fall within a reasonable, slightly conservative, range relative to measurements.

TABLE G-1. MEASURED LEVELS AND NOISE REDUCTION - LAX

Building	Room	Exterior		Interior		NR	
		Av.	σ	Av.	σ	Av.	σ
Imperial School	2	85.7	4.1	56.8	3.2	28.9	1.8
	11	85.0	5.2	57.5	3.1	27.5	2.6
	6	82.6	5.1	50.8	3.4	31.8	2.5
Lennox H.S.	4 Bldg 3	71.3	3.3	50.9	4.2	20.4	2.3
	3 Bldg 6	75.6	5.6	53.7	5.7	21.9	2.0
	3 Bldg 4	71.3	3.7	57.9	3.3	13.4	1.5
Felton Ave. School	9	89.1	5.0	70.8	5.6	18.3	2.4
	5	83.8	6.5	65.7	8.7	18.1	2.7
	11	86.1	6.0	66.9	7.3	19.2	2.4
Clyde Woodworth School	4	78.4	5.1	57.0	4.1	21.4	1.5
Morningside H.S.	J2	86.0	3.4	63.2	3.9	22.8	1.1
	V2	76.0	8.4	54.5	6.3	21.5	3.5
Centinella Hospital	5114	68.3	3.5	40.8*	1.9	30.0*	1.7
	8128	68.9	3.2	42.6**	1.5	29.9**	1.0
Westchester H.S.	F9	67.2	5.4	51.3	4.9	16.0	1.3
Imperial Hospital	227	69.4	2.3	46.0	2.0	23.3	2.3
	224	69.2	2.3	47.4	1.9	21.3	2.7

* Counting only 5 interior measurements above background.

** Counting only 4 interior measurements above background.

TABLE G-2. MEASURED LEVELS AND NOISE REDUCTION - BOS

Building	Room	Exterior Av.	Exterior σ	Interior Av.	Interior σ	NR Av.	NR σ
Winthrop Community Hospital	319	82.8	7.7	60.3	9.0	22.5	3.6
	271	78.1	6.1	49.4	5.7	28.8	1.6
Winthrop JHS	206	76.3	4.9	56.3	3.1	20.0	3.4
	220	68.8	6.9	45.0	7.3	23.8	6.5
Julia Ward Howe School	Left Front	84.7	2.4	63.1	2.0	21.6	1.0
	Right Front	85.7	3.5	60.7	3.3	25.0	1.0
Cherverus School	8	77.2	4.9	58.8	4.0	18.4	2.4
	2	78.9	2.4	61.0	1.4	18.0	1.9
Chapman School	Left	79.0	4.8	70.0	5.5	9.0	1.6
	Right	78.3	4.2	64.7	4.3	13.4	2.3
Chelsea Memorial Hospital	201	74.3	2.9	50.3	2.0	24.1	3.0
	210	78.9	5.3	55.0	4.3	24.0	3.8
Williams School	15	75.7	4.9	57.2	4.8	18.5	1.5
	20	77.2	3.9	58.1	3.6	19.0	0.6

TABLE G-3. MEASURED LEVELS AND NOISE REDUCTION - DEN

Building	Room	Exterior Av.	Exterior σ	Interior Av.	Interior σ	NR Av.	NR σ
Clyde Miller Elem. School	5	72.9	4.5	57.7	3.9	16.9	1.0
Park Lane Elem. School	20	91.5	6.3	57.4	5.3	34.1	2.9 *
	6	87.9	3.9	53.1	3.3	34.8	2.6 *
Sable School	Faculty DiningRoom	85.7	6.0	70.3	4.3	15.5	2.7
	4	79.6	5.1	50.6	5.1	28.7	1.5
North JHS	13	84.5	6.2	59.4	3.2	25.0	5.2
	12	87.6	3.4	63.5	3.3	24.1	0.7
Fitzsimons Hospital	4133	81.9	2.9	56.4	3.6	25.5	1.0
	4062	81.7	3.7	56.3	4.0	25.3	1.5
Boston Elem. School	1	87.6	2.6	61.8	2.8	25.8	1.8
Paris Elem. School	1	61.5	3.3	41.6	1.9	19.9	2.0

* Wall with windows facing away from aircraft. Microphone on wall facing aircraft approximately 10 dB self-shielding.

TABLE G-4. PREDICTED AND MEASURED NOISE REDUCTION - LAX

Building	Room	Predicted	Meas'd	Δ
Imperial School	2	25.8	28.9	-3.1
	11	25.8	27.5	-1.7
	6	31.8	31.8	0
Lennox H.S.	4 Bldg 3	21.4	20.4	1.0
	3 Bldg 6	21.4	21.6	-0.2
	3 Bldg 4	21.4	18.0	3.4
Felton Ave. School	9	19.2	18.3	0.9
	5	19.2	18.1	1.1
	11	19.2	19.2	0.0
Clyde Woodworth School	4	18.0	21.4	-3.4
Morningside H.S.	J2	18.3	22.8	-4.5
	V2	20.1	21.5	-1.4
Centinella Hospital	5114	25.7	30.0	-4.3
	8128	25.7	29.9	-4.2
Westchester H.S.	F9	19.0	16.0	3.0
Imperial Hospital	227	24.0	23.3	0.7
	224	24.0	21.9	2.1

$\overline{\Delta} = -0.4$, $\overline{|\Delta|} = 2.2$, $(\overline{\Delta^2})^{\frac{1}{2}} = 2.6$

TABLE G-5. PREDICTED AND MEASURED NOISE REDUCTION - BOS

Building	Room	Predicted	Meas'd	Δ
Winthrop Hospital	319	22.0	21.7	0.3
	271	28.0	28.8	-0.8
Cherverus School	8	20.0	18.4	1.6
	2	20.0	18.0	2.0
Winthrop J.H.S.	206	28.0	23.0	5.0
	220	25.0	27.0	-2.0
Chapman School	3rd Fl., left	14.2	9.0	5.2
	3rd Fl., rt.	14.2	13.4	0.8
Julia Ward Howe School	Left	22.0	21.6	0.4
	Right	22.0	25.0	-3.0
Williams School	15	21.6	18.5	3.1
	20	20.6	19.0	1.6
Chelsea Memorial Hospital	201	26.9	24.1	2.8
	210	26.9	25.0	1.9

$\overline{\Delta} = 1.3$, $\overline{|\Delta|} = 2.2$, $\left(\overline{\Delta^2}\right)^{\frac{1}{2}} = 2.6$

TABLE G-6. PREDICTED AND MEASURED NOISE REDUCTION - DEN

Building	Room	Predicted	Meas'd	Δ
Clyde Miller Elem. School	Classroom	18.0	16.9	1.1
Park Lane Elem. School	20*	33.0	34.3	-1.3
	6*	33.0	34.8	-1.8
Sable School	Faculty DiningRoom	16.5	15.5	1.0
	4	22.9	28.7	-6.0
North J.H.S.	13	21.0	25.0	-4.0
	12	23.9	24.1	-0.2
Fitzsimons Hosp.	4133	26.5	25.5	1.0
	4062	26.5	25.3	1.2
Boston Elem.School	1	21.5	25.8	-4.3
Paris Elem.School	1	21.5	19.9	1.6

$\overline{\Delta} = -1.2$, $\overline{|\Delta|} = 2.1$, $(\overline{\Delta^2})^{\frac{1}{2}} = 2.7$

* Includes 10 dB shielding due to windows facing away from aircraft.

TABLE G-7. SUMMARY OF STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN PREDICTED AND MEASURED NR

				90% Confidence Limit		
Airport	N*	Mean	σ	Lower	Upper	About Mean
LAX	17	-0.62	2.55	-1.70	0.46	$\pm$1.08
BOS	14	1.35	2.34	0.24	2.46	$\pm$1.11
DEN	11	-1.06	2.65	-2.51	0.38	$\pm$1.45

* No. of rooms measured for each city

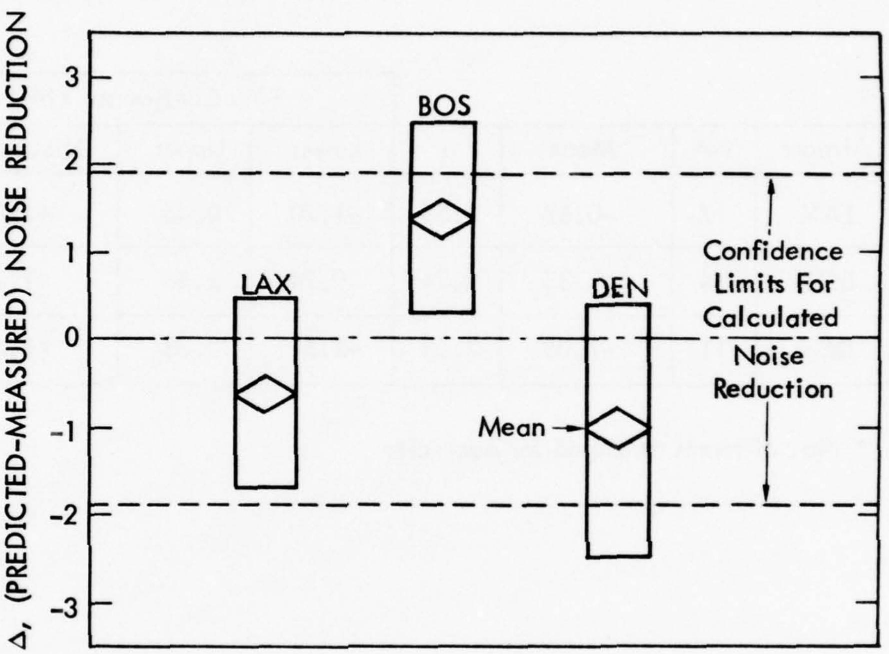

FIGURE G-1. COMPARISON OF 90 PERCENT CONFIDENCE LIMITS FOR PREDICTED MINUS MEASURED VALUES OF NOISE REDUCTION FOR THREE AIRPORTS. (THE MEAN DIFFERENCE FOR EACH CITY IS DESIGNATED BY THE DIAMOND.) FOR COMPARISON THE ANTICIPATED 90% CONFIDENCE LIMITS ACCORDING TO CALCULATED VALUES OF NOISE REDUCTION. (SEE TABLE B-1 IN APPENDIX B.)

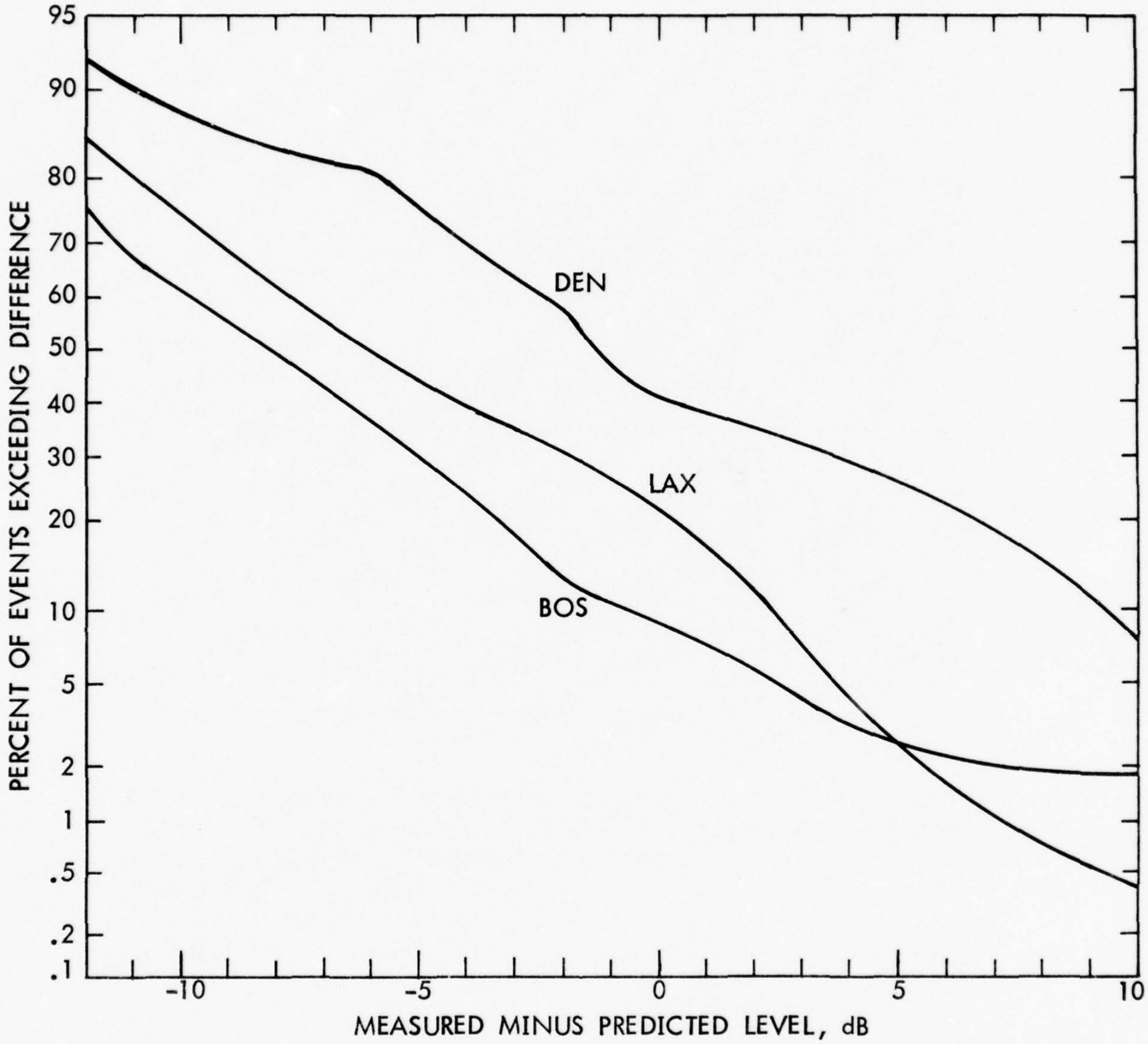

FIGURE G-2. DISTRIBUTIONS OF MEASURED AIRCRAFT NOISE LEVELS RE: PREDICTED AROUND THREE AIRPORTS

APPENDIX H

SOUNDPROOFING REHABILITATION WORKSHEETS

NOISE INSULATION ANALYSIS

Building: Newton Estates School   Room: Classroom

Exterior Noise: NEF 43   Average Peak Level 95

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 264 ft^2	98%
Walls	4" brick & 8" block	2%
Roof	$7\frac{1}{2}$" concrete & insulation	nil

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with double glazing. Provide mechanical ventilation as needed.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and block.

NR = 37

Stage III Rehabilitation

Action:

NR =

Comments:

ATL

NOISE INSULATION ANALYSIS

Building: Longino School — Room: Second Floor

Exterior Noise: NEF 35 — Average Peak Level 85

Measured Noise Reduction (LAX, DEN, BOS, only) ----

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 180 ft^2	95%
Walls	4" brick & 8" block	1%
Roof	2" concrete, 2" insulation, roofing, acoustic tiles	4%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and block to match wall. Cement ½" fiberboard and 5/8" gypsumboard, then new acoustic tiles, to ceiling.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments: Existing NR the same, Stage I NR = 34 and Stage II NR = 41 on first floor.

NOISE INSULATION ANALYSIS

Building: Lake Shore High School Room: Classroom

Exterior Noise: NEF 38 Average Peak Level 90

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 210 ft^2	99%
Walls	4" brick & 8" block	nil
Roof	$2\frac{1}{2}$" concrete, 3" air space, acoustic tiles	See Comments

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 34

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and block to match walls.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments: Roof transmission negligible provided joints between tiles are well sealed. This must be verified (and corrected if need be) before other rehabilitation.

NOISE INSULATION ANALYSIS

Building: Eastern School Room: 2nd Story Classroom

Exterior Noise: NEF 37 Average Peak Level 83

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 240 ft^2	96%
Walls	4" brick & 8" block	nil
Roof	2" concrete & 2" insulation & roofing, acoustic tiles	3%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 31

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and block. Cement ½" fiberboard, 5/8" gypsumboard, then acoustic tiles to ceiling on second floor.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments: First floor original and Stage II NR the same as second. First floor Stage I NR = 33.

NOISE INSULATION ANALYSIS

Building: College Park High School Room: Second Story Classroom

Exterior Noise: NEF 41 Average Peak Level 87

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 195 ft^2	99%
Walls	10" concrete	nil
Roof	2" concrete, 3/4" plaster on lath ceiling	1%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = 21

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with 9" brick.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments: Assuming at least 2" air space between roof slab and ceiling. If not, must cement ½" fiberboard and 5/8" gypsumboard to second story ceiling before other rehabilitation. First floor NR almost the same.

NOISE INSULATION ANALYSIS

Building: Woodward Academy Room: Top Floor Classroom

Exterior Noise: NEF 35 Average Peak Level 73

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 80 ft^2	97%
Walls	8" brick	2%
Roof	6" concrete, $\frac{1}{2}$" plaster ceiling	1%

Interior Absorption: 1250 Sabins.

Predicted Noise Attenuation = 29

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 39

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks.

NR = 43

Stage III Rehabilitation

Action:

NR =

Comments: See comment for College Park H.S. First and second story Stage I NR = 40, Stage II NR = 46.

NOISE INSULATION ANALYSIS

Building: William Fountain School Room: Classroom

Exterior Noise: NEF 35 Average Peak Level 75

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 120 ft^2	99%
Walls	8" brick	nil
Roof	6" slab, acoustic tile ceiling	1%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{24}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 36

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick.

NR = 43

Stage III Rehabilitation

Action:

NR =

Comments: Assuming at least 2" air space between roof slab and ceiling. Joints between tiles must also be well sealed. Otherwise, must correct as described in comments for Lake Shore H.S. and/or College Park H.S.

NOISE INSULATION ANALYSIS

Building: Crawford Long School   Room: Second Story Classroom

Exterior Noise: NEF 33   Average Peak Level 73

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 225 ft^2	99%
Walls	8" brick	nil
Roof	6" concrete, acoustic tile ceiling	nil

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments: See comment for William Fountain School. For first floor, Stage II NR = 45.

NOISE INSULATION ANALYSIS

Building: Samuel Young School

Room: Classroom

Exterior Noise: NEF 40

Average Peak Level 100

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 250 ft^2	99%
Walls	confusing, but brick & block, small area	nil
Roof	2" gypsum deck, built up roofing, 12" space, $\frac{1}{2}$" acoustic tile	nil

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with 9" brick.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments: Joints between acoustic tiles must be well sealed.

NOISE INSULATION ANALYSIS

Building: St. John School   Room: Classroom

Exterior Noise: NEF 40   Average Peak Level 85

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazing, most of one wall	99%
Walls	8" brick, one wall corner room	nil
Roof	6" concrete, acoustic tile ceiling	nil

Interior Absorption: 1250 Sabins.

Predicted Noise Attenuation = $\boxed{23}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 35

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks.

NR = 43

Stage III Rehabilitation

Action:

NR =

Comments: Assuming 2" air space between concrete slab and acoustic tiles. Also, joints between tiles must be well sealed.

NOISE INSULATION ANALYSIS

Building: Imperial School Room: 2 & 11

Exterior Noise: NEF 45 Average Peak Level 93

Measured Noise Reduction (LAX, DEN, BOS, only) 28

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, wood sash, 180 ft^2	82%
Walls	9" Brick	2%
Door	Solid wood, weatherstripped	15%
Roof	Builtup roofing, fiberboard ceiling, attic space	1%

Interior Absorption: 1200 Sabins.

Predicted Noise Attenuation = $\boxed{26}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 32

Stage II Rehabilitation

Action: Stage I, plus install acoustic seals around door. Any hollow core doors must be replaced with solid at least 1 3/4" thick.

NR = 37

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks, same as exterior wall. Replace existing doors with acoustic double doors, or construct entrance vestibule using well sealed solid core doors.

NR = 42

Comments: 1/3 of window area facing away from aircraft.

NOISE INSULATION ANALYSIS

Building: Imperial School Room: 6

Exterior Noise: NEF 45 Average Peak Level 93

Measured Noise Reduction (LAX, DEN, BOS, only) 32

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	None; space filled with stucco/frame construction	16%
Walls	Same as 2 & 11	8%
Door	" " "	72%
Roof	" " "	3%

Interior Absorption: 1200 Sabins.

Predicted Noise Attenuation = 32

Stage I Rehabilitation

Action: Install acoustic seals around door.

NR = 37

Stage II Rehabilitation

Action: Remove stucco/frame window filling and replace with bricks. Install double door or entrance vestibule.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments: Existing room is similar to Stage I rehabilitation of Rooms 2 & 11; stucco/frame window filling is not significantly more effective than double glazing.

NOISE INSULATION ANALYSIS

Building: Lennox High School Room: 4, Bldg.3; 3, Bldg.6; 3, Bldg.4

Exterior Noise: NEF 38 Average Peak Level 80

Measured Noise Reduction (LAX, DEN, BOS, only) 20.4, 21.6, 18.0

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, steel sash, 167 ft^2	56%
Door	Hollow core wood, no seals	42%
Walls	6" concrete & stucco	1%
Roof	Built up roofing, fiberboard ceiling, attic space	nil

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{21.4}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Replace door with 1 3/4" solid core door, weatherstripped.

NR = 30

Stage II Rehabilitation

Action: Stage I, plus acoustical seals around door.

NR = 33

Stage III Rehabilitation

Action: Eliminate windows and fill space with 6" concrete & stucco. Replace door with acoustic double door, or construct entrance vestibule using well sealed solid core doors.

NR = 38

Comments:

NOISE INSULATION ANALYSIS

Building: Felton Avenue School   Room: 9, 5, 11

Exterior Noise: NEF 41   Average Peak Level 90

Measured Noise Reduction (LAX, DEN, BOS, only) 18.3, 18.1, 19.2

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, wood sash, 270 ft^2	85%
Walls	Stucco/gypsumboard frame constr., uninsulated	3%
Door	Steel, no seals	4%
Roof	Builtup roofing, fiberboard ceiling, vented attic space.	9%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{19.2}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 26

Stage II Rehabilitation

Action: Stage I, plus install acoustic seals on door and install acoustic baffles in attic vents.

NR = 30

Stage III Rehabilitation

Action: Eliminate windows and replace with stucco/gyp frame construction. Insulate walls and attic, install second layer $\frac{1}{2}$" gypsumboard on walls. Replace door with acoustic double doors, or construct entrance vestibule using well sealed solid core doors.

NR = 35

Comments:

NOISE INSULATION ANALYSIS

Building: Clyde Woodworth School Room: 4

Exterior Noise: NEF 37 Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) 21.4

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 240 ft^2	63%
Walls	Wood/stucco/gyp frame const., uninsulated	5.4%
Doors	2 hollow core wood, no seals	32%
Roof	Builtup roofing, fiberboard ceiling	nil

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = 18

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Replace doors with 1 3/4" solid core, weatherstripped.

NR = 27

Stage II Rehabilitation

Action: Eliminate windows and replace with stucco/gyp frame construction. Add ½" gypsum-board to interior of walls. Insulate walls and attic. Replace doors with double acoustic doors or vestibules with well sealed solid core doors.

NR = 37

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Morningside High School   Room: J2

Exterior Noise: NEF 37   Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) 22.8

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 340 ft^2	80%
Doors	2 steel, no seals	18%
Walls	Brick	1%
Roof	Builtup roofing, fiberboard ceiling	nil

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{18.3}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip doors.

NR = 27

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Replace doors with double acoustic doors or vestibules using well sealed solid core doors.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Morningside High School Room: V2

Exterior Noise: NEF 37 Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) 21.5

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 150 ft^2	65%
Doors	2 Steel, no seals	32%
Walls	Stucco/plaster frame construction	3%
Roof		nil

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{20.1}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip doors.

NR = 29

Stage II Rehabilitation

Action: Eliminate windows and fill space with wall construction. Insulate walls and roof. Add $\frac{1}{2}$" gypsumboard to interior of walls. Replace doors with double acoustic doors or vestibule with well sealed solid core doors.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Westchester High School Room: F9

Exterior Noise: NEF 33 Average Peak Level 75

Measured Noise Reduction (LAX, DEN, BOS, only) 16

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, wood sash	50%
Doors	2 solid core wood, no seals	48%
Roof	6" concrete	1%
Walls	8" concrete	1%

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = 19

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Install acoustic seals on doors.

NR = 36

Stage II Rehabilitation

Action: Eliminate windows and fill space with concrete. Replace doors with acoustic double doors or construct entrance vestibule using well sealed solid core doors.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Figueroa Street School Room: Classroom

Exterior Noise: NEF --- Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 120 ft^2	95% - 100%
Walls	9" Brick & Stucco	nil
Roof	Builtup roofing, plaster ceiling	5% (2nd floor)

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Insulate roof.

NR = 34

Stage II Rehabilitation

Action: Eliminate windows. Insulate roof.

NR = 38

Stage III Rehabilitation

Action:

NR =

Comments:

AD-A069 702 TRANS SYSTEMS CORP VIENNA VA F/G 1/5

STUDY OF SOUNDPROOFING PUBLIC BUILDINGS NEAR AIRPORTS.(U)

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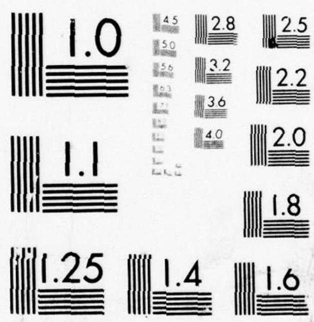

MICROCOPY RESOLUTION TEST CHART
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NOISE INSULATION ANALYSIS

Building: Lawndale High School   Room: Top Floor/Lower Floor

Exterior Noise: NEF ---   Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 70 ft^2 to 150 ft^2	50%/100%
Walls	8" concrete or block	nil
Roof	6" concrete	nil
Doors	2" steel, 1st floor only	50%/—

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{23}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Install acoustic seals on doors.

NR = 34

Stage II Rehabilitation

Action: Eliminate windows. Double acoustical doors or vestibule.

NR =

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Centinella Hospital Room: 5114, 8128

Exterior Noise: NEF 25 Average Peak Level 78

Measured Noise Reduction (LAX, DEN, BOS, only) 30, 29.9

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed	100%
Walls	concrete	nil
Roof		nil

Interior Absorption: 125 Sabins.

Predicted Noise Attenuation = $\boxed{25.7}$

Stage I Rehabilitation

Action: Replace window with sealed double glazing. Provide mechanical ventilation as needed.

NR = 37

Stage II Rehabilitation

Action: Eliminate window and fill space with concrete or bricks.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Imperial Hospital Room: 227, 224

Exterior Noise: NEF 34 Average Peak Level 70

Measured Noise Reduction (LAX, DEN, BOS, only) 23.3, 21.9

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	¼" glass, 6' x 6'	99%
Walls	9" Brick	1%
Roof	6" concrete, suspended acoustic ceiling	nil

Interior Absorption: 140 Sabins.

Predicted Noise Attenuation = $\boxed{24}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 34

Stage II Rehabilitation

Action: Eliminate windows. Fill in space with bricks.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Grant Elementary School Room: Classroom

Exterior Noise: NEF 30 Average Peak Level 82

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 140 ft^2	78%
Roof	Sheathing & shingle, vented attic, plaster ceiling	22%
Wall	12" brick	nil

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 28

Stage II Rehabilitation

Action: Stage I, plus acoustically baffle attic vents.

NR = 35

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks. Baffle attic vents.

NR = 42

Comments:

NOISE INSULATION ANALYSIS

Building: Adeline Gray School Room: 6

Exterior Noise: NEF 32 Average Peak Level 90

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 165 ft^2	74%
Walls	12" brick	nil
Doors	2 solid wood, no seals, shielded by porch	23%
Roof	Sheathing & shingles, plaster ceiling, insulated	1%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip exterior doors.

NR = 31.0

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Install acoustic seals on doors. Glue ½" fiberboard, followed by 5/8" gypsumboard, to ceiling. Apply new acoustic tiles to ceiling

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Lincoln Elementary School Room: Classroom

Exterior Noise: NEF 36 Average Peak Level 90

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 180 ft^2	39%
Walls	8" Brick & 5/8" plaster	1%
Roof	1" sheathing & shingles, plaster ceiling, vented attic	49%
Doors	2 solid wood, no seals, shielded by porch	11%

Interior Absorption: 1000 Sabins.

Predicted Noise Attenuation = $\boxed{20}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Insulate attic and acoustically baffle attic vents. Weatherstrip doors.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Modify attic as in Stage I. Install acoustic seals on doors.

NR = 39

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Skiff Elementary School   Room: Second Floor Classroom

Exterior Noise: NEF 39   Average Peak Level 94

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 180 ft^2	64%
Walls	12" concrete block	3%
Roof	1" sheathing & shingles, acoustic tile ceiling, vented attic.	5%
Door	Solid wood, no seals	28%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip door.

NR = 29

Stage II Rehabilitation

Action: Eliminate windows and fill space with 12" concrete blocks. Acoustically baffle attic vents. Install acoustic seals on door.

NR = 34

Stage III Rehabilitation

Action: Stage II, plus cement ½" fiberboard followed by 5/8" gypsumboard to interior of exterior walls. Alternate wall modification is to add stud framing, insulation and gypsumboard to existing walls.

NR = 40

Comments: For first floor classrooms NR is within 1dB of these values.

NOISE INSULATION ANALYSIS

Building: Wilson Hawkins Elementary School   Room: Second Floor Classrooms

Exterior Noise: NEF 40   Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 180 ft^2	66%
Walls	Brick	nil
Roof	1" sheathing & shingles, ac. tile ceiling vented attic	5%
Door	Solid wood, no seals	29%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip door.

NR = 29

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Acoustically baffle attic vents. Install acoustic seals on door.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments: Same as Skiff school except walls are brick instead of block. Note that brick is better for soundproofing, so that wall modifications are not needed to achieve NR = 40.

NOISE INSULATION ANALYSIS

Building: Dunbar Elementary School Room: Classroom

Exterior Noise: NEF 30 Average Peak Level 83

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 135 ft^2	77%
Walls	15" brick, plaster interior	nil
Roof	7/8" sheathing, ashetop shingles, plaster coating vented & insulated attic space	22%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Acoustically baffle attic vents.

NR = 34

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Baffle attic vents.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Silvestre Herrera Elementary School   Room: 2

Exterior Noise: NEF 36   Average Peak Level 93

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 155 ft^2	36%
Walls	4" brick & 4" concrete block	nil
Roof	Steel joists, sheathing & comp. shingles, acoustic tiles on plaster ceiling, vented attic.	63%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{19}$

Stage I Rehabilitation

Action: Acoustically baffle attic vents. Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate Windows and fill space with bricks. Insulate attic and baffle attic vents.

NR = 40

Stage III Rehabilifation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Ann Ott (Stevenson) School   Room: Classroom

Exterior Noise: NEF 40   Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 200 ft^2	72%
Walls	Brick and plaster	nil
Doors	2 wood with windowpanels, unsealed	19%
Roof	Sheathing & composition shingles, ac. tile ceiling, vented attic space.	9%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{20}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip doors.

NR = 28

Stage II Rehabilitation

Action: Stage I, plus insulate attic and acoustically baffle attic vents.

NR = 31

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks. Replace doors with 1 3/4" solid wood with acoustic seals. Insulate attic & baffle vents.

NR = 41

Comments:

NOISE INSULATION ANALYSIS

Building: Arizona Children's Hospital Room: Patient Rooms

Exterior Noise: NEF --- Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 45 ft^2	100%
Walls	Brick, block & grout, 10" total	nil
Roof	3" concrete, insulation, plaster ceiling	nil

Interior Absorption: 125 Sabins.

Predicted Noise Attenuation = $\boxed{19}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 31

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Arizona State Hospital   Room: Patient Room

Exterior Noise: NEF 27   Average Peak Level 65

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	2 sealed $\frac{1}{4}$" glass, 5" x 8'	8%
Walls	10" brick	nil
Roof	10" concrete, plus insulation, roofing & plaster	nil
Door	Wood or metal, no seals	92%

Interior Absorption: 125 Sabins.

Predicted Noise Attenuation = $\boxed{18}$

Stage I Rehabilitation

Action: Weatherstrip door.

NR = 24

Stage II Rehabilitation

Action: Replace doors with 1 3/4" solid core wood with acoustic seals.

NR = 28

Stage III Rehabilitation

Action: Stage II, plus either double glaze windows or eliminate and fill with brick.

NR = 35

Comments: Noise reduction of 42 possible if eliminate windows and install acoustic double doors or entrance vestibule with acoustically sealed solid core-doors.

NOISE INSULATION ANALYSIS

Building: Dunbar Elementary School Room: Classroom

Exterior Noise: NEF 36 Average Peak Level 83

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	jalousie, 2" air gap, plastic. 170 ft^2	29%
Walls	8" concrete block with ½" stucco	35%
Roof	6" concrete slab, acoustic tile ceiling	3%
Door	Solid wood weatherstripped	34%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = 29

Stage I Rehabilitation

Action: Eliminate windows and fill space with 8" block. Cement ½" fiberboard, then 5/8" gypsumboard to interior of exterior walls. Install acoustic seals on door.

NR = 40

Stage II Rehabilitation

Action:

NR =

Stage III Rehabilitation

Action:

NR =

Comments: Roof transmission negligible, so first and second floor NR the same. Existing structure is a well balanced acoustic design — door and window transmission are just comparable to wall.

NOISE INSULATION ANALYSIS

Building: Citrus Grove Elementary School   Room: Classroom

Exterior Noise: NEF 35   Average Peak Level 79

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Jalousie, 210 ft^2	81%
Doors	2 solid wood, no seals	15%
Walls	8" concrete block	2%
Roof	4" concrete slab	2%

Interior Absorption: 1600 Sabins.

Predicted Noise Attenuation = 18

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip doors.

NR = 29

Stage II Rehabilitation

Action: Eliminate windows and fill space with concrete block and acoustic tiles to match walls. Cement 5/8" gypsumboard, then new acoustic tiles, over existing tiles on walls and ceiling. Install acoustic seals on doors.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Weatley Elementary School Room: Classroom

Exterior Noise: NEF 35 Average Peak Level 85

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 210 ft^2	59%
Door	Solid wood, no seals	37%
Walls	8" concrete block & stucco	1%
Roof	6" concrete slab	2%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = 22

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Install acoustic seals in door.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with concrete block. Cement ½" fiberboard, then 5/8" gypsumboard, to ceiling and walls. Install new acoustic tiles on ceiling. Replace door with acoustic double doors or vestibule.

NR = 43

Stage III Rehabilitation

Action:

NR =

Comments: Ceiling treatment not needed in first story rooms of 2 story sections.

NOISE INSULATION ANALYSIS

Building: Booker T. Washington School   Room: 3rd Story Classroom

Exterior Noise: NEF 35   Average Peak Level 83

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 230 ft^2	95%
Walls	8" concrete block & stucco, ½" plaster	2%
Roof	6" concrete slab	3%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = 21

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 31

Stage II Rehabilitation

Action: Eliminate windows and fill to match walls.

NR = 34

Stage III Rehabilitation

Action: Stage II, plus treat walls and ceiling with ½" fiberboard and 5/8" gypsumboard cemented in place. Replace acoustic tiles on ceiling.

NR = 44

Comments: On first and second floors, Stage I NR = 32, Stage II NR = 37, Stage III NR = 47.

NOISE INSULATION ANALYSIS

Building: Auburndale Elementary School Room: Classroom

Exterior Noise: NEF 30 Average Peak Level 75

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 170 ft^2	8.2%
Walls	8" adobe brick, 8" concrete block	nil
Roof	1" planks, builtup roofing, acoustic ceiling	10.2%
Doors	2 solid wood, no seals	7.7%
Vents	60 ft^2 open louvered vents, below roof overhang	73.2%
AC Unit	6 ft^2 opening	0.6%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{11}$

Stage I Rehabilitation

Action: Either eliminate louvered vents or construct acoustical baffles. Baffles must be constructed on both the inside and the outside. Provide mechanical ventilation as needed.

NR = 17

Stage II Rehabilitation

Action: Stage I, plus replace windows with sealed double glazing, install clay tiles on roof, replace tile ceiling with ½" gypsumboard and new acoustic tiles, install acoustic seals on doors, and acoustically baffle AC unit.

NR = 30

Stage III Rehabilitation

Action: Stage II, except for window modification. Eliminate windows and fill space with brick. Install insulation in roof.

NR = 35

Comments:

NOISE INSULATION ANALYSIS

Building: Kensington Elementary School Room: Classroom

Exterior Noise: NEF 38 Average Peak Level 84

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 170 ft^2	7.4%
Door	Solid wood, weatherstripped	2.0%
Vents	3' x 28' louvered vent below roof overhang	91.2%
Roof	6" concrete slab	0.2%
Walls	8" block & ½" stucco	1.7%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{11}$

Stage I Rehabilitation

Action: Either eliminate vents or acoustically baffle. Baffles must be constructed both inside and outside. Provide mechanical ventilation as needed.

NR = 21

Stage II Rehabilitation

Action: Stage I, plus replace windows with sealed double glazing and install acoustic seals on doors.

NR = 30

Stage III Rehabilitation

Action: Stage I, plus acoustic seals on doors. Eliminate windows and fill space with block. Cement ½" fiberboard and 5/8" gypsumboard to interior of exterior walls and ceiling.

NR = 39

Comments:

NOISE INSULATION ANALYSIS

Building: Buena Vista Elementary School Room: Classroom

Exterior Noise: NEF 40 Average Peak Level 85

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 160 ft^2	98%
Walls	8" block & stucco, ½" plaster	2%
Roof	6" concrete slab, plaster ceiling	nil

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with block, stucco and plaster to match walls.

NR = 36

Stage III Rehabilitation

Action: Stage II, plus cement ½" fiberboard and 5/8" gypsumboard to interior of exterior walls.

NR = 44

Comments:

NOISE INSULATION ANALYSIS

Building: Robert E. Lee Junior High School　　Room: Top Story Classroom

Exterior Noise: NEF 40　　Average Peak Level 86

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 160 ft^2	77%
Vents	Single glazed, 67 ft^2, shielded by hall	3%
Doors	2 solid wood, no seals, shielded by hall	8%
AC Unit	3' x 3' opening	9%
Walls	8" block & ½" stucco	2%
Roof	6" concrete slab	2%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 26

Stage II Rehabilitation

Action: Stage I, plus weatherstrip doors and eliminate or acoustically baffle window AC units.

NR = 31

Stage III Rehabilitation

Action: Eliminate windows and fill space with block. Install acoustic seals on doors. Cement ½" fiberboard, then 5/8" gypsumboard, to interior of exterior walls and ceiling.

NR = 42

Comments: NR in lower stories almost the same. Ceiling treatment not needed in lower stories.

NOISE INSULATION ANALYSIS

Building: Jackson Memorial Hospital   Room: Patient Room

Exterior Noise: NEF 38   Average Peak Level 86

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 20 ft^2	99%
Walls	8" concrete plus brick	1%
Roof	6" concrete	See Comment

Interior Absorption: 250 Sabins.

Predicted Noise Attenuation = $\boxed{27}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 38

Stage II Rehabilitation

Action: Eliminate windows and fill space with concrete and brick.

NR = 45

Stage III Rehabilitation

Action:

NR =

Comments: On top floor, Stage I and Stage II NR = 36, due to transmission through roof. Stage II must therefore include cementing ½" soundboard and 5/8" gypsumboard to ceiling in top story.

NOISE INSULATION ANALYSIS

Building: Pan American Hospital   Room: Patient Room

Exterior Noise: NEF 34   Average Peak Level 78

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 38 ft^2	72%
AC Unit	2' x 3' opening	23%
Walls	8" block and stucco, ½" plaster	2%
Roof	6" concrete slab	2%

Interior Absorption: 200 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Eliminate or acoustically baffle air conditioner vent. Provide mechanical ventilation as needed.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill space with block. Eliminate or baffle AC units. Cement ½" fiberboard followed by 5/8" gypsumboard to interior of exterior walls. Apply same to ceiling on top floor, and replace acoustic tiles.

NR = 39

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Winthrop Community Hospital   Room: 319

Exterior Noise: NEF 38   Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) 21.7

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 108 ft^2	99%
Walls	9" brick and plaster	1%
Roof	6" concrete, gypsumboard ceiling	nil

Interior Absorption: 430 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and plaster.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Winthrop Community Hospital Room: 271

Exterior Noise: NEF 38 Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) 28.8

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 18 ft^2	97%
Walls	9" brick & plaster	3%
Roof	6" concrete, acoustic tile ceiling	nil

Interior Absorption: 250 Sabins.

Predicted Noise Attenuation = $\boxed{28}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 37

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and plaster.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Winthrop Junior High School   Room: 206

Exterior Noise: NEF 36   Average Peak Level 84

Measured Noise Reduction (LAX, DEN, BOS, only) 23.8

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Plastic glazing, 12.5 ft^2	74%
Window Panels	2 layers plastic, 3" airspace. 55 ft^2	20%
Walls	4" brick, 4" block, 2" wood core	5%
Roof	6" concrete, gypsumboard ceiling	nil

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{28}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 36

Stage II Rehabilitation

Action: Eliminate windows and window panels. Fill space with brick and block similar to wall construction.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Winthrop Junior High School Room: 220

Exterior Noise: NEF 36 Average Peak Level 84

Measured Noise Reduction (LAX, DEN, BOS, only) 20.0

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Plastic glazing, 31 ft^2	73%
Window Panels	2 layers plastic, 3" airspace, 135 ft^2	20%
Walls	4" brick, 4" block, 2" wood core	6%
Ceiling	6" concrete, gypsumboard ceiling	nil

Interior Absorption: 700 Sabins.

Predicted Noise Attenuation = 25

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and window panels. Fill space with brick and block similar to wall construction.

NR = 39

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Julia Ward Howe School   Room: First Floor

Exterior Noise: NEF 40   Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) 21.6, 25.0

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 160 ft^2	87%
Walls	Wood siding, plaster interiors, frame construction	13%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 27

Stage II Rehabilitation

Action: Replace windows as in Stage I. Install ½" gypsumboard on interior of exterior walls, resiliently mounted on new 2 x 4 framing with insulation in stud space.

NR = 33

Stage III Rehabilitation

Action: Stage II, plus eliminate windows and fill space with same as wall construction.

NR = 40

Comments: Calculations for 5 window classroom. Some have six smaller windows, dimensions not given, but appear to be same total area from photographs.

NOISE INSULATION ANALYSIS

Building: Julia Ward Howe School　　Room: Second Floor

Exterior Noise: NEF 40　　Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Same as first floor	35%
Walls	" " " "	5%
Roof	Wood & shingle roof, plaster ceiling, vented attic	59%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{18}$

Stage I Rehabilitation

Action: Insulate attic and acoustically baffle vents, plus Stage I of first floor.

NR = 27

Stage II Rehabilitation

Action: Attic improvements as in Stage I, plus Stage II of first floor.

NR = 33

Stage III Rehabilitation

Action: Attic improvements as in Stage I, plus Stage III of firts floor.

NR = 38

Comments:

NOISE INSULATION ANALYSIS

Building: Garfield Junior High School Room: Classroom

Exterior Noise: NEF 40 Average Peak Level 90

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 180 ft^2	100%
Walls	12" x 14" Brick, gyp & plaster on 2 x 4 studs	nil
Roof	1" planks on 24" joists, gyp & plaster ceiling	nil

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{22}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 34

Stage II Rehabilitation

Action: Eliminate windows and fill space with same as exterior wall. Add insulation between roof and ceiling.

NR = 45

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Cherverus School Room: Classroom

Exterior Noise: NEF 37 Average Peak Level 87

Measured Noise Reduction (LAX, DEN, BOS, only) 18.4, 18.0

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 130 ft^2	62%
Door	Solid core wood, no seal	38%
Walls	18" brick with concrete columns	nil
Roof	6" concrete on 18" x 12" joists	nil

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{20}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Weatherstrip exterior door.

NR = 31

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Replace door with acoustic door or vestibule. Install gypsumboard or plaster ceiling on top floor, putting insulation between joists.

NR = 45

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Chapman School Room: Classrooms

Exterior Noise: NEF 38 Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) 9.0, 13.4

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 240 ft^2	100%
Walls	16" brick & 3/4" plaster	nil
Roof	Wood roof, plaster ceiling, vented attic	See Comment

Interior Absorption: 350 Sabins.

Predicted Noise Attenuation = 18

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Install acoustic baffles on attic vents and insulate attic.

NR = 29

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Attic modification as in Stage I.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments: NR = 14 in top floor due to roof. Becomes same as lower floors if attic is baffled and insulated. Measurements in top floor classrooms

NOISE INSULATION ANALYSIS

Building: Williams School Room: Top Floor

Exterior Noise: NEF 37 Average Peak Level 90

Measured Noise Reduction (LAX, DEN, BOS, only) 18.5, 19.0

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 140 ft^2	95%
Roof	Builtup roofing, plaster ceiling	5%
Walls	16" brick	nil

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 31

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks.

NR = 34

Stage III Rehabilitation

Action: Stage II, plus cement ½" fiberboard followed by 5/8" gypsumboard to ceiling on top floor. Alternate ceiling modification is stud framing and insulation, then gypsumboard mounted resiliently.

NR = 41

Comments: For first and second floors, existing NR is the same, Stage I NR = 34, Stage II and Stage III NR = 44.

NOISE INSULATION ANALYSIS

Building: Chelsea Memorial Hospital Room: Patient Rooms 201 & 210

Exterior Noise: NEF 37 Average Peak Level 87

Measured Noise Reduction (LAX, DEN, BOS, only) 24.1, 25.0

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 18 ft^2	100%
Walls	8" brick & 4" concrete block	nil
Roof	6" concrete, acoustic tile ceiling	nil

Interior Absorption: 200 Sabins.

Predicted Noise Attenuation = 27

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 37

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick and block.

NR = 41

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Edwards School Room: Classroom

Exterior Noise: NEF --- Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 160 ft^2	99%
Walls	12" brick	nil
Roof	Builtup roofing, plaster ceiling	1%(top floor only)

Interior Absorption: 370 Sabins.

Predicted Noise Attenuation = 20

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Install insulation between ceiling and roof.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks. Insulate roof as in Stage I.

NR = 40

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Barnes Elementary School   Room: Third Floor Classroom

Exterior Noise: NEF 37   Average Peak Level 86

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 70 ft^2	31%
Skylights	Cupola shape, single glazed, about 80 ft^2	36%
Walls	18" brick	nil
Roof	Builtup roofing, plaster ceiling	33%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{20.8}$

Stage I Rehabilitation

Action: Replace windows and skylights with sealed double glazing. 4" glass blocks may be used to replace skylights, or eliminate and fill with roof construction. Provide mechanical ventilation as needed.

NR = 25

Stage II Rehabilitation

Action: Stage I plus cement ½" fiberboard followed by 5/8" gypsumboard to ceiling on third floor. Alternate ceiling modification is stud framing and insulation, then gypsumboard mounted resiliently.

NR = 33

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks. Eliminate skylights and fill space with roof construction. Stage II ceiling modification on third floor.

NR = 40

Comments: For first and second floors, existing NR = 26, Stage I & Stage II NR = 38, and Stage III NR = 45.

NOISE INSULATION ANALYSIS

Building: Lawrence Memorial Hospital Room: Patient Rooms

Exterior Noise: NEF --- Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 48 ft^2	100%
Walls	9" brick	nil
Roof	6" concrete, plaster ceiling	nil

Interior Absorption: 160 Sabins.

Predicted Noise Attenuation = $\boxed{21}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 33

Stage II Rehabilitation

Action: Eliminate windows and fill space with bricks.

NR = 43

Stage III Rehabilitation

Action:

NR =

Comments:

DEN

NOISE INSULATION ANALYSIS

Building: Clyde Miller School　　Room: Classrooms

Exterior Noise: NEF 29　　Average Peak Level 77

Measured Noise Reduction (LAX, DEN, BOS, only) 16.9

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 200 ft^2	79%
Walls	8" concrete block	1%
Roof	1" Sheathing, plaster ceiling	19%

Interior Absorption: 400 Sabins.

Predicted Noise Attenuation = $\boxed{18}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 24

Stage II Rehabilitation

Action: Stage I, plus add clay or concrete tiles to roof.

NR = 28

Stage III Rehabilitation

Action: Eliminate windows and fill with 8" concrete block. Add tiles to roof as in Stage II.

NR = 32

Comments: Stage III plus adding 2 x 4 framing and plaster to walls and ceiling would give NR = 39.

NOISE INSULATION ANALYSIS

Building: Park Lane School Room: 20, 6

Exterior Noise: NEF 37 Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) 24.3, 24.8

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 160 ft^2	92%
Walls	8" block & 4" brick	1.5%
Roof	Metal deck, brick exterior, plaster ceiling	3%
Unit Vents	3 ft^2 opening	3.5%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{23}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick/block. Eliminate or acoustically baffle unit vent openings.

NR = 36

Stage III Rehabilitation

Action:

NR =

Comments: Measured NR dB higher than shown here because windows faced away from aircraft. Values shown here are for equivalent rooms facing aircraft.

NOISE INSULATION ANALYSIS

Building: Sable School Room: Faculty Dining Room

Exterior Noise: NEF 40 Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) 15.5

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 216 ft^2	92%
Door	Solid wood, weatherstripped	8%
Roof	6" concrete, insulated	nil
Walls	4" brick & 8" block	nil

Interior Absorption: 250 Sabins.

Predicted Noise Attenuation = $\boxed{16.5}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 25

Stage II Rehabilitation

Action: Stage I, plus install acoustic seals on door.

NR = 28

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks and block. Replace door with acoustic double door or entrance vestibule.

NR = 36

Comments: Room has very little absorption - could improve existing and rehabilitate attenuation by up to 5 dB by installing carpets, acoustic tile, and hanging heavy drapes over glass interior walls.

NOISE INSULATION ANALYSIS

Building: Sable School　　Room: 4

Exterior Noise: NEF 40　　Average Peak Level 92

Measured Noise Reduction (LAX, DEN, BOS, only) 28.7

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 190 ft^2	89%
Door	Solid wood, weatherstripped	11%
Walls	8" block & 4" brick	nil
Roof	6" concrete, insulated	nil

Interior Absorption: 1,000 Sabins.

Predicted Noise Attenuation = $\boxed{22.9}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 30

Stage II Rehabilitation

Action: Stage I, plus install acoustic seals on door.

NR = 35

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks and block. Replace door with acoustic double door or entrance vestibule.

NR = 42

Comments:

NOISE INSULATION ANALYSIS

Building: Montview School   Room: Classroom

Exterior Noise: NEF 37   Average Peak Level 88

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 75 ft^2	32%
Walls	40% block & Brick, 60% stucco/plaster	10%
Door	Hollow core wood, rubber seals	44%
Roof	Builtup roofing, plaster ceiling, insulated	9%
Unit Vents	2 per room, 6 ft^2 total opening	5%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{20.6}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Replace door with 1 3/4" solid core door, weatherstripped.

NR = 26

Stage II Rehabilitation

Action: Stage I, plus add clay or concrete tiles to roof, eliminate or acoustically baffle unit vents, install acoustic seals on door, insulate stucco/plaster portion of walls and add second layer of lathing and plaster

NR = 33

Stage III Rehabilitation

Action: Eliminate windows and fill to match wall. Insulate wall. Cement ½" fiberboard and 5/8" gypsumboard to interior of plaster portion of wall. Replace door with solid core wood door with acoustic seals. Modify roof and attic vents as in Stage II.

NR = 39

Comments:

NOISE INSULATION ANALYSIS

Building: North Junior High School   Room: 12

Exterior Noise: NEF 36   Average Peak Level 78

Measured Noise Reduction (LAX, DEN, BOS, only) 24.1

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 70 ft^2	53%
Glass Blocks	160 ft^2, in place of window	7%
Walls	12" brick, tile interior	nil
Unit Vents	Opening 4 ft^2	6%
Roof	Steel joists, gypsum deck, plaster ceiling	33%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = $\boxed{23.9}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 27

Stage II Rehabilitation

Action: Stage I, plus add clay or concrete tiles to roof.

NR = 31

Stage III Rehabilitation

Action: Eliminate glass blocks and windows, fill space with bricks. Eliminate or acoustically baffle unit vent openings. Add clay or concrete tiles to roof.

NR = 40

Comments:

NOISE INSULATION ANALYSIS

Building: North Junior High School Room: 13

Exterior Noise: NEF 36 Average Peak Level 78

Measured Noise Reduction (LAX, DEN, BOS, only) 25

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 210 ft^2	80%
Walls	12" brick, tile interior	nil
Unit Vents	4 ft^2 opening	3%
Roof	Steel joists, gypsum deck, plaster ceiling	17%

Interior Absorption: 630 Sabins.

Predicted Noise Attenuation = 21

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 27

Stage II Rehabilitation

Action: Stage I, plus add clay or concrete tiles to roof.

NR = 31

Stage III Rehabilitation

Action: Eliminate windows and fill space with bricks. Eliminate or acoustically baffle unit vent openings. Add clay or concrete tiles to roof.

NR = 40

Comments:

NOISE INSULATION ANALYSIS

Building: Fitzsimons Hospital Room: 4133, 4062

Exterior Noise: NEF 35 Average Peak Level 80

Measured Noise Reduction (LAX, DEN, BOS, only) 25.5, 25.3

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 15 ft^2	100%
Walls	12" masonry	nil
Roof	Concrete slab	nil

Interior Absorption: 160 Sabins.

Predicted Noise Attenuation = $\boxed{26.5}$

Stage I Rehabilitation

Action: Replace window with sealed double glazing. Provide mechanical ventilation as needed.

NR = 38

Stage II Rehabilitation

Action: Eliminate window and fill space with masonry to match wall.

NR = 42

Stage III Rehabilitation

Action:

NR =

Comments:

NOISE INSULATION ANALYSIS

Building: Boston Elementary School Room: 1

Exterior Noise: NEF ______ Average Peak Level 85

Measured Noise Reduction (LAX, DEN, BOS, only) 25.8

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 200 ft^2	92%
Walls	12" brick & ½" plaster	nil
Roof	Brick exterior, plaster ceiling	3%
Skylights	4' x 4' glass block, 4 in each room	2%
Unit Vents	4.5 ft^2 opening	4%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = $\boxed{21.5}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 30

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick. Eliminate skylights. Eliminate unit vents or acoustically baffle openings.

NR = 37

Stage III Rehabilitation

Action:

NR = ______

Comments: Identical to Paris School.

NOISE INSULATION ANALYSIS

Building: Paris Elementary School Room: 1

Exterior Noise: NEF 30 Average Peak Level 65

Measured Noise Reduction (LAX, DEN, BOS, only) 19.9

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 200 ft^2	92%
Walls	12" brick & ½" plaster	nil
Roof	Brick exterior, plaster ceiling	3%
Skylights	4' x 4' glass block, 4 in each room	2%
Unit Vents	4.5 ft^2 opening	4%

Interior Absorption: 800 Sabins.

Predicted Noise Attenuation = 21.5

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 30

Stage II Rehabilitation

Action: Eliminate windows and fill space with brick. Eliminate skylights. Eliminate unit vents or acoustically baffle openings.

NR = 37

Stage III Rehabilitation

Action:

NR =

Comments: Identical to Boston School.

NOISE INSULATION ANALYSIS

Building: Denver General Hospital Room: 13' x 15' Patient Room

Exterior Noise: NEF --- Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 65 ft^2	100%
Walls	5" concrete, 2" foam insulation, $\frac{1}{2}$" gypsumboard	nil
Roof	3" concrete slab plus insulation	nil

Interior Absorption: 150 Sabins.

Predicted Noise Attenuation = $\boxed{20}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed.

NR = 32

Stage II Rehabilitation

Action: Eliminate windows and fill with wall construction.

NR = 38

Stage III Rehabilitation

Action:

NR =

Comments: Attenuation and rehabilitation virtually the same for 26' x 21' patient rooms.

NOISE INSULATION ANALYSIS

Building: Elyria Room: Classroom

Exterior Noise: NEF --- Average Peak Level ---

Measured Noise Reduction (LAX, DEN, BOS, only) ---

Analysis of Existing Noise Insulation

Component	Description	% Total Transmission
Windows	Single glazed, 130 ft^2	42%
Walls	13" masonry and brick	1%
Roof	Wood & composition shingles, uninsulated vented attic.	54%
Unit Vent	3 ft^2 opening	2%

Interior Absorption: 500 Sabins.

Predicted Noise Attenuation = $\boxed{18}$

Stage I Rehabilitation

Action: Replace windows with sealed double glazing. Provide mechanical ventilation as needed. Install acoustic baffles in attic vents.

NR = 30

Stage II Rehabilitation

Action: Eliminate windows and fill space with masonry and brick to match wall. Install acoustic baffles in attic vents. Eliminate or acoustically baffle unit vents.

NR = 36

Stage III Rehabilitation

Action:

NR =

Comments:

APPENDIX I

CATEGORY A & B NOISE REDUCTION IMPROVEMENTS

TABLE I-1. CATEGORY A & B NOISE REDUCTION IMPROVEMENTS - LAX

Building		Existing NR	Category A NR	Category A ΔNR	Category A Stage	Category B NR	Category B ΔNR	Category B Stage
Schools								
Imperial School	Room 6	32			Exists	42	10	II
	Room 2 & 11	26	37	11	I	42	16	III
Lennox H.S.		21	33	12	II	38	17	III
Felton Avenue		19	30	11	II	35	16	III
Clyde Woodworth		18	27	9	I	37	19	II
Morningside H.S.	Room J2	18	27	9	I	40	22	II
	Room V2	20	29	9	I	40	20	II
Westchester		19	36	17	I	41	22	II
Figueroa St.		22	34	12	I	39	20	II
Lawndale H.S.		23	34	11	I	41	22	II
Average				10.6			17.8	
Standard Deviation				3.1			4.0	
Hospitals								
Centinella		26	37	11	I	41	15	II
Imperial		24	34	10	I	42	18	II
Average				10.5			16.5	
Standard Deviation				0.7			2.1	

TABLE I-2. CATEGORY A & B NOISE REDUCTION IMPROVEMENTS - PHX

Building	Existing NR	Category A NR	Category A ΔNR	Category A Stage	Category B NR	Category B ΔNR	Category B Stage
Schools							
Grant Elementary	22	35	13	II	42	20	III
Adeline Gray	22	31	9	I	41	19	II
Lincoln Elementary	20	32	12	I	39	19	II
Skiff Elementary	21	29	8	I	40	19	III
Wilson Hawkins Elementary	21	19	8	I	40	19	II
Dunbar Elementary	22	34	12	I	40	18	II
Silvestre Herrera Elementary	19	33	14	I	40	21	II
Ann Ott (Stevenson)	20	31	11	II	41	21	III
Average			10.9			19.5	
Standard Deviation			2.3			1.1	
Hospitals							
Arizona Children's	19	31	12	I	41	22	II
Arizona State	18	28	10	II	42	24	IV
Average			11.0			23.0	
Standard Deviation			1.4			1.4	

TABLE I-3. CATEGORY A & B NOISE REDUCTION IMPROVEMENTS - MIA

Building	Existing NR	Category A NR	Category A ΔNR	Category A Stage	Category B NR	Category B ΔNR	Category B Stage
Schools							
Dunbar Elementary	29	-	-	Exists	40	11	I
Citrus Grove Elementary	18	29	11	I	40	22	II
Weatly Elementary	22	33	11	I	43	21	II
Booker T. Washington	21	31	10	I	44	23	III
Aubumdale Elementary	11	30	19	II	35	24	II
Kensington Elementary	11	30	19	II	39	28	III
Buena Vista Elementary	22	33	11	I	44	22	III
Robert E. Lee J.H.S.	21	31	10	II	42	21	III
Average			13.0			21.5	
Standard Deviation			4.1			4.8	
Hospitals							
Jackson Memorial	27	38	11	I	45	18	II
Pan American	22	32	10	I	39	17	II
Average			10.5			17.5	
Standard Deviation			0.7			0.7	

TABLE I-4. CATEGORY A & B NOISE REDUCTION IMPROVEMENTS - BOS

Building	Existing NR	Category A NR	Category A ΔNR	Category A Stage	Category B NR	Category B ΔNR	Category B Stage
Schools							
Winthrop J.H.S. Room 206	28	36	8	I	42	14	II
Room 220	25	33	8	I	39	14	II
Julia Ward Howe School 1st Floor	22	33	11	II	40	18	III
2nd Floor	18	33	15	II	38	20	III
Garfield J.H.S.	22	34	12	I	45	23	II
Cherverus School	20	31	11	I	45	25	II
Chapman School	18	29	11	I	41	23	II
Williams School	21	31	10	I	41	20	III
Edward School	20	32	12	I	40	20	II
Barnes Elementary School	21	33	12	II	40	19	III
Average			10.00			19.60	
Standard Deviation			2.3			3.6	
Hospitals							
Winthrop Community Room 319	22	33	11	I	42	20	II
Room 271	28	37	9	I	42	18	II
Lawrence Memorial Hospital	21	33	12	I	43	22	II
Chelsea Memorial	27	37	10	I	41	14	II
Average			10.50			18.5	
Standard Deviation			1.3			3.4	

TABLE I-5. CATEGORY A & B NOISE REDUCTION IMPROVEMENTS - ATL

Building	Existing NR	Category A NR	Category A ΔNR	Category A Stage	Category B NR	Category B ΔNR	Category B Stage
Schools							
Newton Estates School	21	32	11	I	37	16	II
Longino School	22	32	10	I	40	18	II
Lake Shore H.S.	22	34	12	I	41	19	II
Eastern School	21	31	10	I	41	20	II
College Park H.S.	21	33	12	I	42	21	II
Woodward Academy	29	39	10	I	43	14	II
William Fountain	24	36	12	I	43	19	II
Crawford Long School	22	33	11	I	42	20	II
Samuel Young	21	33	12	I	42	21	II
St. John School	23	35	12	I	43	20	II
Average Standard Deviation			11.2 0.9			18.8 2.2	
NO HOSPITALS							

TABLE I-6. CATEGORY A & B NOISE REDUCTION IMPROVEMENTS - DEN

Building	Existing NR	Category A NR	Category A ΔNR	Category A Stage	Category B NR	Category B ΔNR	Category B Stage
Schools							
Clyde Miller	18	28	10	II	39	21	IV
Park Lane	23	32	9	I	36	13	II
Sable School (Faculty Dining Rm)	16	28	12	II	36	20	III
Room 4	23	35	12	II	42	19	III
Montview School	21	33	12	II	39	18	III
North J.H.S.							
Room #12	24	31	7	II	40	16	III
Room #13	21	31	10	II	40	19	III
Boston Elementary School	21	30	9	I	37	16	II
Paris Elementary School	21	30	9	I	37	16	II
Elyria	18	30	12	I	36	18	II
Average			10.20			17.6	
Standard Deviation			1.8			2.4	
Hospitals							
Fitzsimons Hospital	26	38	12	I	42	12	II
Denver General	20	32	12	I	38	18	II
Average			12			15.0	
Standard Deviation			0			4.2	

APPENDIX J

A-WEIGHTED CUMULATIVE NOISE METRICS

This study considered aircraft noise in terms of maximum A-weighted noise levels. Another approach to representing noise is in terms of A-weighted cumulative noise metrics. The two most commonly used cumulative metrics are:

$$L_{eq} = \frac{1}{T} \int_{T} 10^{L/10} dt \qquad \text{(J-1)}$$

where L is the instantaneous A-weighted noise level, and T is the time period of interest, and

$$L_{dn} = \frac{1}{24\,hr} \int_{0700}^{2200} 10^{L/10} dt + \int_{2200}^{0700} 10^{(L+10)/10} dt \qquad \text{(J-2)}$$

where the first integral represents daytime and the second represents nighttime.

The noise reductions developed in this study apply to any A-weighted aircraft noise level, not just the maximum. (To compute L_{eq} or L_{dn}, NR would be subtracted from L in Equation (J-1) or (J-2). Because NR is constant for a given building, it may be factored out of the integrals.) NR for L_{eq} and L_{dn} is thus exactly the same as for maximum levels. The building noise reduction and unit cost data developed in this study are equally valid for application to impact expressed as L_{eq} or L_{dn}.

APPENDIX K

STATE AND REGIONAL CONSTRUCTION
COST ADJUSTMENT FACTORS

TABLE K-I

STATE AND REGIONAL BUILDING CONSTRUCTION COST
ADJUSTMENT FACTORS

FAA Region	States	General	Labor	Material
1. New England (ANE)	Maine	.87	.77	.97
	Vermont	.96	.98	.94
	New Hampshire	.91	.82	1.00
	Massachusetts	1.01	.95	1.07
	Rhode Island	1.08	.90	1.25
	Connecticut	.98	.95	1.00
	Regional Factors	.97	.90	1.04
2. Eastern (AEA)	New York	1.03	1.07	.99
	New Jersey	.97	.98	.96
	Pennsylvania	.99	.99	.99
	Maryland	.97	.93	1.01
	Delaware	1.01	1.00	1.01
	Virginia	.87	.71	1.02
	West Virginia	1.00	.94	1.05
	Regional Factors	.98	.95	1.00
3. Southern (ASO)	North Carolina	.73	.48	.98
	South Carolina	.72	.51	.92
	Georgia	.84	.72	.96
	Florida	.96	.98	.93
	Alabama	.79	.63	.94
	Mississippi	.84	.71	.97
	Tennessee	.85	.77	.84
	Kentucky	.94	.86	1.01
	Regional Factors	.83	.71	.94

TABLE K-1 (Cont'd.)

FAA Region	States	General	Labor	Material
4. Great Lakes (AGL)	Ohio	.99	1.00	.98
	Indiana	.96	.94	.97
	Illinois	.99	.98	.99
	Michigan	1.01	1.00	1.01
	Wisconsin	.97	.93	.98
	Minnesota	.99	.94	1.04
5. Southwest (ASW)	Arkansas	.83	.73	.92
	Louisiana	.84	.72	.96
	Oklahoma	.88	.82	.93
	Texas	.84	.74	.93
	New Mexico	.86	.81	.91
	Regional Factors	.85	.76	.93
6. Central (ACE)	Nebraska	.98	.91	1.05
	Kansas	.92	.86	.97
	Missouri	.99	.99	.98
	Iowa	.98	.92	1.05
	Regional Factors	.97	.92	1.01
7. Rocky Mountain (ARM)	Colorado	.91	.92	.89
	Utah	.91	.95	.86
	Wyoming	.94	.89	.98
	Montana	.99	.88	1.10
	North Dakota	.92	.75	1.08
	South Dakota	.87	.73	1.01
	Regional Factors	.92	.85	.99

TABLE K-I (Cont'd.)

FAA Region	States	General	Labor	Material
8. Western (AWE)	Arizona	.98	.95	1.01
	Nevada	1.08	1.13	1.03
	California	1.10	1.16	1.04
9. Northwest (ANW)	Idaho	.95	.87	1.03
	Oregon	1.03	1.02	1.03
	Washington	.99	.98	1.01
	Regional Factors	.99	.96	1.02
10. Pacific - Asia (APC)	Hawaii	1.11	.85	1.36
11. Alaska (AAL)	Alaska	1.27	1.19	1.35

TABLE K-2

SIX REGIONAL BUILDING CONSTRUCTION COST ADJUSTMENT FACTORS[1,2]

	Correction Factors		
	General	Labor	Material
Region A	1.10	1.17	1.03
Region B	1.00	.92	1.07
Region C	.84	.74	.94
Region D	.97	.94	1.00
Region E	.85	.75	.95
Region F	.94	.88	.99
Alaska	1.27	1.19	1.35
Hawaii	1.11	.85	1.36
Puerto Rico	.87	.37	1.36

[1] 1977 Dodge Manual for Building Construction Pricing and Scheduling, McGraw-Hill Information Systems Company, New York, 1976.

[2] 1977 Dodge Construction Systems Costs, McGraw-Hill Information Systems Company, New York, 1976.

APPENDIX L

REGIONAL DELTA NOISE REDUCTION

TABLE L-I

REGIONAL Δ NR BY CATEGORY

Construction Region	Category A		Category B	
	School	Hospital	School	Hospital
A	11	11	18	17
B	11	11	20	23
C	13	11	22	18
D	10	11	20	10
E	11	--	19	--
F	10	12	18	15
National Average	11	11	20	18

APPENDIX M

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

TABLE M-I

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

CONSTRUCTION REGION A

Schools Name	Room No.	Costs Cat. A	Costs Cat. B	Room S.F.
Imperial School	14	$ 4,720	$ 4,924(2) 43,920(3)	12600
Lennox High School	36	164,285	206,235	31248
Felton Avenue School	20	108,836	109,831	18000
Clyde Woodworth Sch.	32	182,080	170,350	30464
Morningside School	72	346,075	393,736	68544
Westchester High Sch.	58	239,027	277,280	43500
Sample School Bldgs.	232	$1,045,023	$1,206,276	204356
Cost Per Sq. Ft.		$ 5.11	$ 5.90	
Cost Per School Room for Region A		$ 4,504	$ 5,199	
Outside NEF 30				
Figueroa Street School		$ 115,815	--	
Lawndale High School		$ 352,329	--	

Hospitals Name	Room No.	Costs Cat. A	Costs Cat. B	Room S.F.
Centinela Hospital	260	$ 847,382	$ 840,768	58500
Imperial Hospital	92	305,367	348,937	17664
Sample Hospitals	352	$1,152,749	$1,189,705	76164
Cost Per Sq. Ft.		$ 15.14	$ 15.62	
Cost Per Hospital Room for Region A		$ 3,275	$ 3,380	

TABLE M-2

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

CONSTRUCTION REGION B

Schools		Costs			Hospitals				
Name	Room No.	Cat. A.	Cat. B.	Room S.F.	Name	Room No.	Cat. A.	Cat. B.	Room S.F.
Grant Elem. School	22	$25,291	$31,605	17050	Children Hospital	70	$25,855	$55,468	13356
Adeline Gray School	7	30,762	57,662	5376	Arizona State Hospital	72	125	55,593	9360
Lincoln Elem. School	12	46,689	46,882	10656	Sample Hospitals	142	$ 25,980	$111,061	22716
Skiff Elem. School	35	47,512	55,965	30844					
Wilson Hawkins Ele.	21	28,531	36,199	18506					
Dunbar Elem. School	17	71,139	84,543	13328					
Herrera Silverstre El.	8	17,544	14,300	6810					
Ann Ott School	21	89,562	89,687	15120					
Sample School Bldgs.	143	$357,030	$416,843	117690					
Cost Per Sq. Ft.		$ 3.03	$ 3.54		Cost Per Sq. Ft.		$ 1.14	$ 4.89	
Cost Per School Room for Region B		$ 2,497	$ 2,915		Cost Per Hospital Room for Region B		$ 183	$ 782	

TABLE M-3

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

CONSTRUCTION REGION C

Schools

Name	Room No.	Costs Cat. A.	Costs Cat. B.	Room S.F.
Dunbar Elementary Sc.	34	--	$23,859	33320
Citrus Grove Ele. Sc.	53	194,931	183,317	44648
Wheatley Elementary	34	175,756	229,880	28560
Booker T. Washington	54	289,699	440,367	60750
Auburndale Ele. Sc.	60	305,593	468,540	50400
Kensington Ele. Sc.	43	22,950	31,221	33540
Buena Vista Ele. Sc.	22	23,861	75,498	16500
Robert Lee Junior H.S.	30	111,616	104,015	23400
Sample School Bldgs.	330	$1,124,406	$1,556,697	291118
Cost Per Sq. Ft.		$ 3.86	$ 5.35	
Cost Per School Room for Region C		$ 3,407	$ 4,717	

Hospitals

Name	Room No.	Costs Cat A.	Costs Cat. B.	Room S.F.
Jackson Memorial Hos.	735	$2,172,927	$2,118,842	194040
Pan American Hospital	88	202,900	249,107	16896
Sample Hospitals	823	$2,375,827	$2,367,949	210936
Cost Per Sq. Ft.		$ 11.26	$ 11.23	
Cost Per Hospital Room for Region C		$ 2,887	$ 2,877	

TABLE M-4

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

CONSTRUCTION REGION D

Schools

Name	Room No.	Costs Cat. A.	Costs Cat. B.	Room S.F.
Winthrop Junior H.S.	45	$23,671	$19,312	33238
Julia Ward Howe Sc.	10	54,005	44,563	8400
Garfield Junior H.S.	27	121,889	135,833	19 64
Cheverus School	18	125,430	142,615	12258
Chapman School	18	95,109	103,828	15480
Williams School	75	342,648	367,447	67155
Barnes Elementary Sc.	52	213,631	338,814	47121
Sample School Bldg.	245	$976,383	$1,152,412	203916
Cost Per Sq. Ft.		$ 4.79	$ 5.65	
Cost Per School Room for Region C		$ 3,985	$ 4,703	
Outside NEF 30				
Edward School		$ 77,481	$ 83,924	

Hospitals

Name	Room No.	Costs Cat. A.	Costs Cat. B.	Room S.F.
Winthrop Community H.	54	$173,296	$171,953	12960
Chelsea Memorial Hos.	28	68,705	67,941	5241
Sample Hospitals	82	$242,001	$239,894	18201
Cost Per Sq. Ft.		$ 13.30	$ 13.18	
Cost Per Hospital Room for Region D		$ 2,951	$ 2,925	
Lawrence Memorial Hospital		$ 37,573	$ 34,081	

TABLE M-5

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

CONSTRUCTION REGION E

Schools					Hospitals		
Name	Room No.	Costs Cat. A.	Cat. B.	Room S.F.	Name	Costs Cat. A.	Cat. B.
Newton Estates Sc.	6	$ 29,180	$26,146	5400	No Sample		
Longino School	13	52,831	91,509	10764			
Lake Shore High Sc.	45	173,756	161,873	29700			
Eastern School	8	33,828	57,381	6624			
College Park H.S.	25	141,587	71,911	16500			
Woodward Academy	26	77,426	75,874	19136			
Fountain School	16	55,814	58,360	12480			
Crawford Long Sc.	42	209,484	222,015	42336			
Samuel R. Young Sc.	22	69,244	66,572	17409			
St. John School	10	42,693	45,239	8640			
Sample School Bldgs	213	$ 885,843	$876,880	168989			
Cost Per Sq. Ft.		$ 5.24	$ 5.19				
Cost Per School Room for Region E		$ 4,159	$ 4,117				

TABLE M-6

COSTINGS OF SAMPLE BUILDINGS (1977 PRICE)

CONSTRUCTION REGION F

Schools: Name	Room No.	Costs: Cat. A.	Costs: Cat. B.	Room S.F.	Hospitals: Name	Room No.	Costs: Cat. A.	Costs: Cat. B.	Room S.F.
Clyde Miller E.S.	5	$18,770	$30,706	3000	Fitzsimons Army Hosp.	611	$965,000	$ 987,374	75182
Parkland School	23	75,465	76,152	19454					
Sable School	26	143,110	117,034	11407					
Montview School	23	88,950	83,711	18216					
North Junior H.S.	25	116,043	117,505	18000					
Boston Elem.	12	69,720	76,736	11729					
Paris School	8	42,833	46,548	8012					
Sample School Bldgs.	122	$554,892	$548,392	89818					
Cost Per Sq. Ft.		$ 6.18	$ 6.11		Cost Per Sq. Ft.		$ 12.84	$ 13.13	
Cost Per School Room for Region F		$ 4,548	$ 4,495		Cost Per Hospital Room for Region F		$ 1,580	$ 1,616	
Outside NEF 30									
Elyria School		$ 14,278	$ 15,267		Denver General Hospital		$ 77,041	$ 65,967	

APPENDIX N

SUMMARY OF PROGRAM COST BY STATE AND CONSTRUCTION REGION

TABLE N-I

SUMMARY OF PROGRAM COST BY STATE AND CONSTRUCTION REGION

Construction Region	State	No. of Airports	Schools: No. of Schools	Schools: No. of Students	Schools: Cost A	Schools: Cost B	Hospitals: No. of Hosp.	Hospitals: No. of Patients	Hospitals: Cost A	Hospitals: Cost B
A (Pacific Coast)	California	38	123	82952	$2819770 (46)	$13296750 (77)	11	3483	$953020 (1)	$6137960 (10)
	Hawaii	15	20	14427	-	3020850 (20)	0	0	0	0
	Total	53	143	97379	$2819770 (46)	$16317600 (97)	11	3483	$953020 (1)	$6137960 (10)
B (Inland West)	Arizona	13	20	11712	$ 119840 (2)	$ 1233055 (18)	3	872	$ 72650 (1)	$ 98550 (2)
	Nevada	5	6	5909	187250 (1)	466400 (5)	1	900	0	422340 (1)
	Total	18	26	17621	$ 307090 (3)	$ 1699455 (23)	4	1772	$ 72650 (1)	$ 520890 (3)
C (Gulf Coast)	Florida	39	85	63602	$2235180 (24)	$ 8287800 (61)	10	4007	$ 89490 (1)	$6835590 (9)
	Louisiana	11	8	4751	160140 (2)	665120 (6)	0	0	0	0
	Puerto Rico	2	4	1665	-	320770 (4)	0	0	0	0
	Total	52	97	70018	$2395320 (26)	$ 9273690 (71)	10	4007	$ 89490 (1)	$6835590 (9)
D (East Central)	Connecticut	5	5	1916	$ 0	$ 362210 (5)	0	0	$ 0	$ 0
	Delaware	0	0	0	0	0	0	0	0	0
	Illinois	21	65	41781	1984350 (24)	4567330 (41)	2	548	0	962500 (2)

*Include 12 Public Health Facilities

TABLE N-I (Cont'd.)

Construction Region	State	No. of Airports	Schools: No. of Schools	Schools: No. of Students	Schools: Cost A	Schools: Cost B	Hospitals: No. of Hosp.	Hospitals: No. of Patients	Hospitals: Cost A	Hospitals: Cost B
D (East Central) (Cont'd.)	Indiana	20	13	6554	$ 494140 (8)	$ 639710 (5)	0	0	$ 0	$ 0
	Maine	8	4	1094	--	206974 (4)	0	0	0	0
	Maryland	3	8	4692	135500 (1)	719670 (7)	1	180	0	310110 (1)
	Massachusetts	8	41	20617	924580 (11)	3015090 (30)	6	1538	132810 (1)	2568620 (5)
	New Hampshire	3	6	2636	--	493920 (6)	0	0	0	0
	New Jersey	8	51	27847	569890 (10)	3810020 (41)	5	999	0	1752400 (5)
	New York	26	180	182373	12002824 (94)	16860042 (86)	20	6438	2558710 (5)	8713960 (15)
	Ohio	20	25	14912	669520 (7)	1914440 (18)	1	186	0	327710 (1)
	Pennsylvania	19	24	12169	187306 (4)	2173154 (20)	1	186	0	327710 (1)
	Rhode Island	1	0	0	0	0	0	0	0	
	Vermont	1	1	464		89380 (1)	0	0	0	
	Virginia	15	14	6694	354690 (1)	893720 (13)	0	0	0	
	West Virginia	9	4	1264	0	239800 (4)	0	0	0	
	Total	167	441	325013	$ 17322800 (160)	$35985560 (281)	36	10075	$2691520 (6)	$ 14963010 (30)
E (Great Lakes and South)	Alabama	15	19	9783	$ --	$1642640 (19)	0	0	0	0
	Arkansas	12	6	3636	--	601080 (6)	0	0	0	0
	Georgia	26	27	17059	989830 (12)	1465890 (15)	1	626	0	1144920 (1)
	Kentucky	7	18	12416	--	2037840 (18)	1	155	0	224090 (1)
	Michigan	26	30	18526	652950 (12)	1766170 (18)	1	626	0	1144920 (1)
	Mississippi	17	11	6252	---	1029250 (11)	0	0	0	0
	North Carolina	18	6	2712	--	448750 (6)	0	0	0	0
	South Carolina	16	8	4788	--	790460 (8)	0	0	0	0

*Include 12 Public Health Facilities

TABLE N-I (Cont'd.)

Construction Region	State	No. of Airports	Schools: No. of Schools	Schools: No. of Students	Schools: Cost A	Schools: Cost B	Hospitals: No. of Hosp.	Hospitals: No. of Patients	Hospitals: Cost A	Hospitals: Cost B
E (Great Lakes and South) (Cont'd.)	Tennessee	14	20	12796	$ 207950 (2)	$ 1889630 (18)	2	1252	$ 0	$ 1829290 (2)
	Wisconsin	19	12	7198	--	1185670 (12)	1	626	0	1144920 (1)
	Total	170	157	95166	$ 1850730 (26)	$12857380 (131)	6	3285	0	$5488140 (6)
F (Central)	Alaska	24	0	0	$ 0	$ 0	0	0	$ 0	$ 0
	Colorado	12	63	35850	$ 2492230 (28)	380270 (35)	14	5496	112361 0(6)	345178 0 (8)
	Idaho	7	0	0	0	0	0	0	0	0
	Iowa	12	6	2500	0	449510 (6)	0	0	0	0
	Kansas	14	5	2320	0	418040 (5)	0	0	0	0
	Minnesota	11	19	9384	350220 (4)	1361990 (15)	1	692	0	728820 (1)
	Missouri	15	11	5914	563990 (6)	525920 (5)	0	0	0	0
	Montana	11	7	3407	113710 (2)	413540 (5)	0	0	0	0
	Nebraska	9	6	2896	0	516930 (6)	0	0	0	0
	New Mexico	13	5	2922	0	561880 (5)	3	584	0	565600 (3)
	North Dakota	6	5	1876	0	337130 (5)	0	0	0	0
	Oklahoma	16	16	7311	0	1312550 (16)	0	0	0	0
	Oregon	8	3	1392	0	251720 (3)	0	0	0	0
	South Dakota	7	4	1983	254690 (3)	107880 (1)	0	0	0	0
	Texas	53	17	11830	363840 (4)	1424920 (13)	2	910	0	1103730 (2)
	Utah	3	1	724	0	112380 (1)	0	0	0	0
	Washington	15	20	9544	0	1258600 (20)	2	502	0	486420 (2)
	Wyoming	12	5	2320	0	418040 (5)	0	0	0	0
	Total	248	193	102173	$4138680 (47)	$13273740 (146)	22	8184	$1123610 (6)	$6336350 (16)

*Include 12 Public Health Facilities

TABLE N-I (Cont'd.)

Construction Region	No. of Airports	Schools: No. of Schools	Schools: No. of Students	Schools: Cost A	Schools: Cost B	Hospitals*: No. of Hosp.	Hospitals*: No. of Patients	Hospitals*: Cost A	Hospitals*: Cost B
All Region Total	708	1057	707370	$28834390 (308)	$89407425 (749)	89	30806	$4930290 (15)	$40281940 (74)
25% Mark-up**				7208600	22351860			1232570	10070490
				$36042990	$111759285			$6162860	$50352430
Total Costs (A+B)				$147,802,275 ($147,800,000)				$56,515,290 ($56,500,000)	
Grand Total Cost (Schools and Hospitals)					≈ $204,300,000				

* Include 12 Public Health Facilities

** Include Overhead - 10 %, Profit - 10 %, and Contingency - 5 %.

APPENDIX O

MEETINGS

In the course of meetings, the following people offered opinions and views.

- Mr. Beavers, Facilities Director of College Park High School, Atlanta, Georgia;
- Mr. Phillips, Director of School Plant Planning, Miami, Florida;
- Mr. Richard Via, Facilities Department, Roanoke School System, Roanoke, Virginia;
- Mr. Murphy, Buffalo School System, Buffalo, New York;
- Mr. Heaslip, Construction Management Associates, New Orleans, Louisiana;
- Mr. Richard E. Mooney, Director of Aviation, Massachusetts Port Authority, Boston, Massachusetts;
- Peter Metz, Massachusetts Executive Office of Transportation and Construction, Boston, Massachusetts;
- Jim Prendergast, Mayor's Office, City of Revere, Massachusetts
- David Charak, Mayor's Office, City of Chelsea, Massachusetts;
- Thomas Reilly, Selectman, Winthrop, Massachusetts;
- Burt Lockwood, Assistant Airport Manager, Los Angeles International Airport, Los Angeles, California;
- Dr. John W. Meyer, Superintendent of Schools, El Segundo Unified School District, California;
- Mrs. V. Bergen, Principal of Imperial Elementary School, Los Angeles California.

APPENDIX P

STATISTICAL ANALYSIS

This section describes the statistical approaches used to analyze the collected data.

A variety of mathematical analyses were performed including:

1. Averaging

2. Analysis of Variance

Averaging

Simple averages were not always used. Many average calculations were performed on the basis of frequency. For example, in determining the average window size and number, and the average room size and number, the frequency average was used in order to develop more representative averages.

The following shows an example of the difference between the frequency average and the simple average. Since the actual numbers of windows directly relate to cost, the simple average would lead to erroneous cost estimates.

FREQUENCY AVERAGE	SIMPLE AVERAGE
Building A	Building A
500 Rooms x 3 Windows per Room x 10 square feet = 15,000	10 square feet
Building B	Building B
100 Rooms x 3 windows x 40 ft^2 = 12,000	40 square feet
$\frac{15,000 + 12,000}{1800 \text{ windows}}$	$\frac{10 + 40}{2}$
Average = 15 ft^2	Average = 25 ft^2

Analyses of Variance

Analyses of variance were performed to ascertain the significance of differences in means and totals. For example, an analysis of variance was performed on the regional cost correction factors in order to determine whether or not the cost correction factors were in fact different. The regional factors were based on average data developed for cities. Averaging data in this manner sometimes produces meaningless averages. If the averages are not sufficiently different from one another, the value of the correction factors has been averaged away. This analysis is performed to insure that this has not happened. The following shows the computational formulas used in the analysis.

ANALYSIS of VARIANCE

$$SS_a = \overline{n}_h \quad [\,(\Sigma\, A^2)/q - G^2/pq\,]$$

$$SS_a = \overline{n}_h \quad [\,(\Sigma\, B^2)/p - G^2/pq\,]$$

$$SS_{ab} = \overline{n}_h \quad [\,(\Sigma\, \overline{AB}^2 - (\Sigma\, A^2/q) - (\Sigma\, B^2/p) + (G^2/pq)\,]$$

$$SS_{w.\,cell} = \Sigma\Sigma SS_{ij}$$

$$\overline{n}_h = \frac{pq}{\Sigma\Sigma(1/n_{ij})}$$

APPENDIX Q

LIST OF AIRPORTS FOR DATA SHEET - BY FAA REGION

FAA Region	Airport Name	Location
#1 ANE	Logan International	Boston, Massachusetts (L)*
	Bradley International	Hartford, Connecticut (M)**
	Portland International	Portland, Maine
	Hartford Brainard	Hartford, Connecticut
	Barnse Municipal	Westfield, Massachusetts
	Danbury Municipal	Danbury, Connecticut
	Fitchburg Municipal	Fitchburg, Massachusetts
#2 AEA	J.F. Kennedy International	New York, New York (L)
	La Guardia	New York, New York (L)
	Newark	Newark, New Jersey (L)
	Philadelphia International	Philadelphia, Pennsylvania (L)
	Greater Pittsburgh	Pittsburgh, Pennsylvania (L)
	Washington National	Alexandria, Virginia (L)
	Dulles International	Chantilly, Virginia (L)
	Greater Buffalo International	Buffalo, New York (M)
	Rochester-Monroe County	Rochester, New York (M)
	Clarence E. Hancock	Syracuse, New York (M)
	Albany County	Albany, New York (M)
	Baltimore-Washington International	Baltimore, Maryland (M)
	Norfolk Regional	Norfolk, Virginia (M)
	L. I. MacArthur	Islip, New York
	Richard E. Byrd Flying Field	Richmond, Virginia
	Morristown Municipal	Morristown, New Jersey
	North Philadelphia	Philadelphia, Pennsylvania
	Roanoke Municipal	Roanoke, Virginia
	Frederick Municipal	Frederick, Maryland
#3 ASO	William B. Hartsfield International	Atlanta, Georgia (L)
	Miami International	Miami, Florida (L)
	Ft. Lauderdale - Hollywood	Ft. Lauderdale, Florida (L)
	Tampa International	Tampa, Florida (L)
	Standiford	Louisville, Kentucky (M)
	Greensboro-High Point-Winston Salem Regional	Greensboro, North Carolina (M)

*Large Hub Airport
**Medium Hub Airport

(Continued)

FAA Region	Airport Name	Location
	Raleigh-Durham	Raleigh-Durham, North Carolina (M)
	Douglas Municipal	Charlotte, North Carolina (M)
	Nashville Metropolitan	Nashville, Tennessee (M)
	Memphis International	Memphis, Tennessee (M)
	Birmingham Municipal	Birmingham, Alabama (M)
	Jacksonville International	Jacksonville, Florida (M)
	McCoy AFB	Orlando, Florida (M)
	Palm Beach International	West Palm Beach, Florida (M)
	Puerto Rico International	San Juan, Puerto Rico (L)
	St. Petersburg, Clearwater	St. Petersburg, Florida
	McGhee Tyson	Knoxville, Tennessee
	Fulton County	Atlanta, Georgia
	Opa Locka	Miami, Florida
	Key West International	Key West, Florida
	Capital City	Frankfort, Kentucky
	Greater Cinncinati	Covington, Kentucky (M)
	Imeson Airport	Jacksonville, Florida
#4 AGL	Minneapolis-St. Paul International	Minneapolis-St. Paul, Minnesota (L)
	O'Hare International	Chicago, Illinois (L)
	Midway	Chicago, Illinois (L)
	Cleveland Hopkins International	Cleveland, Ohio (L)
	Detroit Metropolitan Wayne County	Detroit, Michigan (L)
	General Mitchell Field	Milwaukee, Wisconsin (M)
	Indianapolis Municipal	Indianapolis, Indiana (M)
	James M. Cox Dayton Municipal	Dayton, Ohio (M)
	Port Columbus International	Columbus, Ohio (M)
	Evansville Dress Regional	Evansville, Indiana
	Kent County	Grand Rapids, Michigan
	Pontiac Municipal	Pontiac, Michigan
	Burke Lakefront	Cleveland, Ohio
	Marion Municipal	Marion, Ohio
	Kokomo Municipal	Kokomo, Indiana
	Lost Nation	Mentor, Ohio
#5 ASW	Dallas-Fort Worth Regional	Dallas-Ft. Worth, Texas (L)
	New Orleans International	New Orleans, Louisiana (L)
	Houston Inter-continental	Houston, Texas (L)
	Albuquerque International	Albuquerque, New Mexico (M)
	Tulsa International	Tulsa, Oklahoma (M)
	Will Rogers World	Oklahoma City, Oklahoma (M)
	El Paso International	El Paso, Texas (M)
	San Antonio International	San Antonio, Texas (M)
	Ryan Field	Baton Rouge, Louisiana

(Continued)

FAA Region	Airport Name	Location
	Lubbock Regional	Lubbock, Texas
	Meacham Field	Fort Worth, Texas
	Lakefront	New Orleans, Louisiana
	Lafayette	Lafayette, Louisiana
	Cox Field	Paris, Texas
	Shreveport	Shreveport, Louisiana
#6 ACE	Kansas City International	Kansas City, Missouri (L)
	Lambert-St. Louis Municipal	St. Louis, Missouri (L)
	Eppley Airfield	Omaha, Nebraska (M)
	Wichita Municipal	Wichita, Kansas
	Fairfax Municipal	Kansas City, Missouri
	Springfield Municipal	Springfield, Missouri
	Columbus Municipal	Columbus, Nebraska
	Independence Municipal	Independence, Kansas
	Des Moines Municipal	Des Moines, Iowa
	Tri-City	Cherryvale, Kansas
#7 ARM	Stapleton International	Denver, Colorado (L)
	Salt Lake City International	Salt Lake City, Utah (M)
	Great Falls International	Great Falls, Montana
	Joe Foss Field	Sioux Falls, South Dakota
	Peterson Field	Colorado Springs, Colorado
	Cedar City Municipal	Cedar City, Utah
	Gregory Municipal	Gregory, South Dakota
#8 AWE	San Francisco International	San Francisco, California (L)
	Los Angeles International	Los Angeles, California (L)
	McCarran International	Las Vegas, Nevada (L)
	Metropolitan Oakland International	Oakland, California (L)
	San Diego International	San Diego, California (M)
	Reno International	Reno, Nevada (M)
	Phoenix Sky Harbor International	Phoenix, Arizona (M)
	Tucson International	Tucson, Arizona (M)
	Sacramento Metropolitan	Sacramento, California
	Santa Barbara	Santa Barbara, California
	Van Nuys	Los Angeles, California
	Buckeye Municipal	Buckeye, Arizona
	Rohnerville	Fortuna, California
	Carson	Carson City, Nevada
	Imperial County	Imperial, California
	Hollywood Burbank Airport	Burbank, California
	Clover Field	Beverly Hills, California
	Luke Air Force Field	Valencia, Arizona

(Continued)

FAA Region	Airport Name	Location
#9 ANW	Seattle-Tacoma International	Seattle, Washington (L)
	Spokane International	Spokane, Washington (M)
	Portland International	Portland, Oregon (M)
	Mahlon Sweet International	Eugene, Oregon
	Boise Air Terminal	Boise, Idaho
	Hillsboro	Hillsboro, Oregon
	Grant County	Moses Lake, Washington
#10 APC	Honolulu International	Honolulu, Hawaii (L)
	General Lyman Field	Hilo, Hawaii (L)
	Kahului	Kahului, Hawaii (M)
	Lihue	Lihue, Hawaii (M)
	Heeia	Kailua, Hawaii
	Hana Airport	Kailua, Hawaii
	Maui Airport	Maui, Hawaii
# 11 AAL	Anchorage International	Anchorage, Alaska (M)
	Fairbanks International	Fairbanks, Alaska
	Nenana Airfield	Nenana, Alaska

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